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CLAY and SHALE RESOURCES
IN
SOUTHWESTERN PENNSYLVANIA

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with

LABORATORY TESTS

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CLAY AND SHALE RESOURCES IN SOUTHWESTERN PENNSYLVANIA

By HENRY LEIGHTON

SUMMARY

This report is a description of the available clays and shales of the southwestern counties of Pennsylvania as determined from a field survey by the writer, and a series of physical tests made on 139 samples by Prof. J. B. Shaw and G. J. Bair of State College and chemical analyses by students under the direction of Prof. T. W. Mason of State College.

The clay resources of the area include (1) very plastic surface clays of the Carmichaels formation deposited during earlier stages of the main streams of the region and generally known as "terrace clays," and (2) bedded clays and shales of the Permian, Pennsylvanian, Mississippian, and Devonian periods.

The Carmichaels clay is utilized by only one firm at present, for making flower pots. In earlier days it was used in making stoneware and roofing tile and, on account of its excellent plasticity, it presents interesting possibilities.

Shales suitable for making common and face brick and, in some cases paving brick or sewer pipe, are abundant throughout the bedded deposits, with the Conemaugh group of the Pennsylvanian period furnishing the bulk of the best material.

Plastic fire clays are seldom found higher in the section than the Brush Creek coal of the lower Conemaugh series but below that bed they are fairly common. The principal horizons where fire clays are obtained are the Brush Creek and Mahoning of the Conemaugh, and the Upper Freeport, Bolivar, Lower Kittanning and Brookville horizons of the Allegheny group. The Lower Kittanning and the Bolivar horizons are the most important. Good flint clay is confined chiefly to the Bolivar beds.

Buff colored clays carrying considerable lime are common in the Conemaugh group and may resemble fire clays but are of little value. Red clays occur in the Conemaugh, Mauch Chunk and Catskill beds and are generally suited to brick manufacture.

The report is accompanied by many tables of analyses and tests and by a colored geologic map of southwestern Pennsylvania.

INTRODUCTION

A study of the clay resources of Pennsylvania was initiated by the State Geological Survey in 1925. Mr. George Longcor of Marcus Hook, Pa., collected many samples in that year, especially from Fayette, Westmoreland, Somerset, Clearfield, Centre, and Clinton counties. These samples were sent to State College where physical tests were made in the ceramic laboratory by Prof. J. B. Shaw and his assistants, and a number of chemical analyses were made by students under the direction of Prof. T. W. Mason. The results of this study were published as Bulletin M 10 of the State Geological Survey in 1928 under the title Fire Clays of Pennsylvania (partial report) by J. B. Shaw.

Since that time the investigation has been continued by the writer, working during parts of 1929, 1930, and 1931. He has made a field study of the clays and shales as exposed along railroads, main highways, in brick yard quarries, and in coal and clay mines and has collected about 250 samples. The physical tests of these samples have been completed by Prof. Shaw and Mr. G. J. Bair and the chemical analyses by students under Prof. Mason.

This report discusses the results of these studies in the southwestern counties and includes the description and tests of 139 samples of clay and shale.

Work is to be continued over the rest of the State and additional samples collected and tested. Reports covering other sections of the State will appear from time to time.

GEOLOGICAL RELATIONS OF CLAYS AND SHALES

Among the important mineral resources of western Pennsylvania are its deposits of clay and shale. These are used extensively in the manufacture of fire brick and other refractories, paving brick, sewer pipe, face and common brick, drain tile, and many minor clay products. In fact, clay or shale suitable for the manufacture of practically every type of clay product except white ware is found within the district discussed in this report. The manufacture of clay products in normal times is carried on by approximately 91 plants employing over 5,000 men, and the value of the products is about \$15,000,000 per year. Included in the above, there are about 15 plants manufacturing fire brick, white ware, crucibles, and other products from clays brought in from other parts of the State and from other States. These plants employ about 1940 persons.

The portion of the State under consideration in this report comprises the southwestern and western counties, Greene, Washington, Fayette, Westmoreland, Armstrong, Allegheny, Butler, Lawrence, Beaver and Indiana. The area centers around Pittsburgh and is traversed by the Monongahela, Youghiogheny, Conemaugh, Allegheny, Ohio, and Beaver rivers, whose valleys form the major lines of transportation for the district.

Physiography

The region is part of the Appalachian Plateaus province, a rolling highland which stretches westward from the Allegheny Mountains. The general elevation of the plateau in western Pennsylvania averages around 1200 feet above sea level and it is considered to be part of a great plain which was brought down nearly to sea level by erosion and later was uplifted to its present height. The major streams and their intricately branching tributaries have carved the former plateau into a maze of steep-sided valleys. Stream erosion has progressed to such a stage that little flat upland is left and very little level land has been developed along the valley bottoms. Roads and railroads are forced to follow the crooked stream valleys or the high winding divides. The main streams have cut sharp valleys 400 to 500 feet below the uplands and it is along their narrow lowlands that most of the industrial development is located. The uplands are more largely given over to agriculture and to residential development.

The most pronounced exceptions to the general topography are Chestnut and Laurel ridges, which rise 1000 feet above the surrounding valleys. They extend northeast from the West Virginia line to and beyond Conemaugh River. Chestnut Ridge lies just east of Uniontown, Connellsville, and Latrobe and Laurel Ridge parallels it to the east, their crests being 7 or 8 miles apart. They are rocky, wooded ridges which present a distinct barrier to transportation, the railroads crossing them only through the deep river gaps while the main highways use the gaps or cross the ridges with steep gradients.

The gaps through Chestnut Ridge are formed by Youghiogheny River, Loyalhanna Creek, and Conemaugh River; those through Laurel Ridge by Youghiogheny and Conemaugh rivers.

Stratigraphy

The plateau area is underlain by a great series of nearly horizontal layers of sandstone, shale, clay, limestone, conglomerate, and coal. These beds of rock represent sands, muds, gravels, and limy sediments formed on a sea bottom or along river banks many millions of years ago. The coal beds represent peat bogs formed from the decaying vegetation of the swampy areas. Some of the limestones and shales contain fossil shells and other organisms of a former sea, while the coal and its accompanying shales carry abundant plant fossils. Although these layers of rock appear horizontal, movements of the earth's crust have tilted and folded them slightly. Their general inclination or dip is toward the south or west of south but they show gentle waves which trend in a northeast direction. These waves are almost imperceptible along the Ohio line but to the east they become more pronounced, as in the Murrys ville and Fayette anticlines, the Uniontown syncline, and the more prominent folds which form Chestnut and Laurel ridges. The up-folds are known as anticlines and the down-folds or troughs are termed synclines. Where the folding is greatest the beds may dip as much as 15° from the horizontal but over the greater part of western Pennsylvania the dip is not more than 25 or 50 feet per mile.

The sedimentary beds exposed in the district under discussion are about 4,000 feet thick. The portions of the 4,000 feet to be seen in any one locality depend upon the depth of valley cutting and upon the amount of tilting or deformation to which the beds have been subjected. Toward the north the lower parts of the pile of strata are exposed; in the southwestern corner of the State only higher beds are seen, and in the gaps of Chestnut and Laurel ridges the very oldest and lowest of the strata exposed in western Pennsylvania are brought to light.

The entire column of strata as seen in the exposures of this portion of the State has been divided into various subdivisions by the geologists. They are as follows, with the oldest and first deposited strata at the bottom. The thickness given is an average and varies from one locality to another.

Generalized Geologic Column.

System	Series	Group	Average thickness in feet
Permian	Dunkard	{ Greene	700
		{ Washington	400
Pennsylvanian	{ Pittsburgh	{ Monongahela	350
		{ Conemaugh	650
		{ Allegheny	300
	{ Pottsville		200
Mississippian	{ Mauch Chunk		125
	{ Pocono		1000
Devonian	Upper Devonian		300

The map (Plate I) indicates the main areas in which these subdivisions appear on the surface. It will be noted that the Permian occupies the southwest corner and that each lower or older series surrounds it as a marginal zone, the Monongahela dipping under the Dunkard, the Conemaugh under the Monongahela, and so on through series and groups. By a careful study of this map the underlying structure can be worked out and the location of any particular series of coals or clays can be determined. For instance, if the clay worker knows that good clay is likely to occur near the top of the Allegheny group the map gives him the localities in which the upper Allegheny group crops out.

The general features of these groups of strata will now be described.

HARD ROCK STRATA

Greene Group. This group is made up of alternating shales, sandstones, thin, unimportant coals, and thin, fresh-water limestones. It contains many shales suitable for making brick but practically no clays of greater value. It includes the strata above the Upper Washington limestone.

Washington Group. The Washington group includes the strata from the top of the Upper Washington limestone down to the top of the Waynesburg coal. It is made up of thin, unimportant coal beds, buff or reddish shales, coarse sandstones, and thin, fresh-water limestones. The thickest limestone is the Upper Washington at the top of the group and the thickest sandstone is the Waynesburg at the base of the group. No fire clays or high grade clays are present but the group carries abundant shales suitable for making brick.

Monongahela Group. This includes the strata between the top of the Waynesburg coal and the bottom of the Pittsburgh coal. Besides these two workable coals it carries the Redstone, Sewickley, and other coals locally workable. This group contains a large amount of fresh-water limestone which may make up one-half of the section. Shales and sandstones are also present. The coals may carry thin underclays but these are seldom if ever of value. The Pittsburgh coal at the base of the group has a parting of shaly fire clay between the main bench of coal and the roof coal. This parting is quite refractory and is used in the manufacture of low grade or low heat duty refractories. The shales of the group are normal brick shales.

Conemaugh Group. This includes the rocks from the base of the Pittsburgh coal down to the top of the Upper Freeport coal. It is made up of shales, sandstones, thin fresh-water limestones and coals of small value. In its lower half there are three interesting marine limestones, the Ames, Pine Creek, and Brush Creek. Brick shales are abundant and also thick beds of red clay of excellent quality for making brick. Associated with the fresh-water limestones are gray crumbly clays which often resemble fire clays but are usually very limy and of little value. Within the lower 50 or 100 feet of the group clays of a better grade are found. These are suitable for the manufacture of sewer pipe or fire brick of the lower heat duty. They are usually found below the horizon of the Brush Creek limestone and coal, or still farther down in the Mahoning sandstone horizons.

Allegheny Group. This includes the beds from the top of the Upper Freeport coal down to the base of the shale or clay beneath the Brookville coal, or to the top of the heavy sandstones of the Pottsville series. The group contains many valuable coals which, in order from top to bottom, are the Upper Freeport, Lower Freeport, Upper, Middle, and Lower Kittanning, the Clarion and the Brookville. These coals are usually underlain by plastic fire clays and sometimes by flint clay. The two most important positions for the fire clays are about 20 feet below the Upper Freeport coal (the Bolivar clay), and just under the Lower Kittanning coal. The underlays of all the coals of the Allegheny group are worthy of attention and may be of value in the manufacture of fire brick, sewer pipe, paving brick, or buff face brick. Red-burning brick shales are also common in the group. Between the Lower Kittanning coal and the Clarion coal is a marine limestone, the Vanport, which is of considerable economic value and is also an important marker or key bed for determining the position of the strata in the geologic column.

Pottsville Series. The Pottsville series is very thin in western Pennsylvania as compared to its thickness in eastern parts of the State. It is made up chiefly of coarse white sandstones or conglomerates of rounded white quartz pebbles. Between the thick sandstone beds there are several intervals in which coals, shales and clays may occur. The two most often encountered are the Mercer and the Sharon horizons. Either of these intervals may carry valuable fire clays but their correlation is difficult and some clays classed as of Mercer age may actually be in the lower part of the Allegheny group. The better clays of the Pottsville series are found in the counties to the east of the district here described. In western Pennsylvania there are few clays or shales of value in the Pottsville series.

Mauch Chunk Series. This name is given to a mass of bright red and green shales and clays which underlie the Pottsville series. They are generally absent in northwestern Pennsylvania and in the extreme western counties but are prominent among the rocks of Chestnut and Laurel ridges. A marine limestone, the Greenbrier, lies in the shales near the base of the series. These shales, when not too sandy, are excellent brick material but are often, in this district, somewhat inaccessible.

Ste. Genevieve (Loyalhanna) limestone. This is a limy sandstone or limestone much used for crushed stone and paving block.

Pocono Series. A series of sandstones and shaly sandstones several hundred feet thick. Neither the Loyalhanna nor the Pocono carries clays or shales of any value.

Upper Devonian Series. Below the Pocono sandstones and exposed only in the core of Chestnut and Laurel ridges are a series of sandy shales carrying marine fossils. This series represents the Catskill and the Chemung divisions of the Devonian. Some of the shale might be used for making brick but in general it is too sandy or slaty to be of any value. It is generally exposed in the deeper gaps through the ridges.

UNCONSOLIDATED DEPOSITS

Recent Deposits. After the deposition of this great thickness of sedimentary strata on low lands or in a sea bottom, the whole series was uplifted and slightly folded. Erosion working over a long period of time and coupled with some further uplifts eventually produced a topography somewhat like that of the present and in the period just preceding the Glacial period, western Pennsylvania was a hilly region traversed by large wide streams following, in general, the courses of the major streams of today. During the advance and retreat of the first great sheet of ice which covered northwestern Pennsylvania during the Glacial period these wide valleys were filled to great depths by sands, gravels and clays deposited by the overtaxed streams. Later events brought about a deepening of the channels and the old levels were left as high terraces. These terraces, still covered with their deposits of sand, gravel and clay are to be seen along the Allegheny, Ohio, Monongahela and others of the older valleys. Those along the Allegheny and Ohio rivers are covered with true glacial gravels brought down from the ice front. The level upon which they lie is known as the Parker strath and the deposits are of the Illinoian glacial epoch. The terraces which border the Monongahela and Youghiogheny rivers flowing from the south, are contemporaneous with those of the Allegheny River region but are covered with local sands, gravels and clays called the Carmichaels formation. The terrace stands about 200 feet above the river at Pittsburgh. An abandoned loop of this older stream forms the plain on which East Liberty, Wilkinsburg, and Oakland are built.

The interest of the clay worker in these terraces lies in the fact that they often carry very plastic yellow or gray clays which are of considerable value and can be manufactured into earthenware, flower pots, face brick, and sewer pipe. They are, of course, unconsolidated deposits and are subject to all the irregularities which one would expect in river clays. Their spotty, irregular occurrence has been the greatest drawback to their use.

A third type is the clay deposited directly from the melting glacier. The glaciers, in their southerly advance, barely touched the northwest part of this district and, as far as known, left no clays of any importance. To the north in Lawrence, Mercer, and Crawford counties no doubt there are clays of this type. They are usually plastic, red-burning, suitable for making common brick and drain tile.

A fourth type of clay in the district is that deposited by the present streams during high water stages. These are known as flood-plain clays. The low lands along our main streams contain much of this material. It is generally a plastic, sometimes sandy clay suitable only for the manufacture of common brick and drain tile. In the early days it was much used but at present no plants are using it because shales make more satisfactory brick and often are in a more favorable situation for quarrying or digging.

To summarize, four types of clay are available in the district:

1. Bedded clay and shale of Devonian to Permian age.
2. High terrace clay of early glacial age, chiefly Carmichaels formation.
3. Glacial clays of doubtful value.
4. Flood plain clays, formerly used for making common brick.

CLASSIFICATION OF CLAYS

Clay is a substance difficult to define. It might be described as a natural earth made up of finely divided mineral particles, chiefly hydrous aluminum silicates, and, in general, having plastic properties when wet and drying to a firm body. No definite chemical or mineral composition can be given for it and its chief qualities are fineness of grain and plasticity. The only exception to this definition would be that of flint clay which is non-plastic.

Clays have been studied and classified by various methods, of which the most important are chemical analysis, dehydration curves, petrographic microscope, ultra-microscope, and X-rays. The study of the diffraction patterns produced from clays under X-rays is a rather recent and a very promising mode of attack and is yielding good results in the definition and study of the purer clays.

Mineralogy of Clays and Shales

Clay is a rock made up of minute scales and shreds of mineral matter known as the clay minerals, with smaller amounts of extraneous impurities such as quartz grains, small scales of mica, pyrite crystals, carbonaceous matter, limonite, and other minerals. The clay minerals are frequently aggregated into masses dispersed with difficulty but when they are separated they can be seen as clear scales ranging in size from two to twelve microns (.002 to .012mm.). Still smaller particles are revealed with the ultra-microscope, these forming the colloidal portion of the clay.

Recent study of the clay minerals places them in three or four groups as shown in the following table.

Table 1. Clay Minerals

Mineral	Chemical formula	Crystal form	Index of refraction	Birefringence	Per cent SiO ₂	Per cent Al ₂ O ₃	Per cent H ₂ O
Kaolinite	Al ₂ O ₃ .SiO ₂ .2H ₂ O	Monoclinic plates and worm-like bundles	1.557-1.566	.002	46.5	39.5	14
Beidellite	Al ₂ O ₃ .3 SiO ₂ .nH ₂ O	Orthorhombic scales and shreds	1.49-1.536 iron-rich 1.55-1.60	.032-.051	51	23.7	20.3
Halloysite	Al ₂ O ₃ .2 SiO ₂ .nH ₂ O	Isotropic-amorphous	1.47-1.542	none	43.5	36.9	19.6
Montmorillonite	Al ₂ O ₃ .5 SiO ₂ (MgCa)O.nH ₂ O	Rhombic plates	1.51	.023	50.6	17.23	23.32*

* CaO-3.21; MgO-4.56.

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The purer unconsolidated clays, such as kaolin, contain identifiable kaolinite scales and bundles of scales. The less pure surface clays seem to be made up largely of iron-rich beidellite scales with occasionally small amounts of kaolinite. Shales are largely made up of beidellite scales oriented in parallel position. This orientation, together with variations in grain size and in impurities, produces the laminated structure of the shales. Plastic fire clays apparently are mixtures of halloysite and unoriented scales of beidellite and kaolinite, compacted into an aggregate very difficult to break up.

Flint clay seems to be halloysite or some similar amorphous compound which, to a varying degree, has been recrystallized into kaolinite, often showing the worm-like bundles, and, in lesser degree, to beidellite.

Among the extraneous impurities there should be noted the almost constant presence of minute rods and grains of a yellowish, highly refracting mineral which probably is rutile. These grains have a size of about one micron (.001mm.). They are found uniformly scattered throughout the amorphous base of the flint clays and in lesser amounts in the kaolin portion and in the plastic clays. Small scales of muscovite are common in clays, and still smaller scales of sericitic mica are present and may alter to a substance known as hydromica. Although some authors think that hydromica is a transitional mineral between mica and kaolinite, others question the identity of the mineral and believe it to be beidellite.

The coloring matter in clay is largely made up of tiny specks of opaque or dark brown organic matter and dots of limonite.

The coarser impurities, such as quartz, pyrite, feldspar, zircon, and others, can generally be washed from the clay and studied separately. Unless in large amounts they have little effect upon the properties of the clay and therefore require little attention.

The quality of a clay seems to depend upon the clay minerals themselves and these demand much more study than they have received. The work of Ross and Shannon and others has brought out the fact that these clay minerals may, in themselves, furnish the content of iron, calcium or magnesium which has often been attributed to extraneous impurities.

Among the more important papers upon the mineralogy of clays are the following:

Galpin, S. L. Studies of flint clays and their associates, Trans. Amer. Cer. Soc. XIV, p. 307, 1912.

Larsen, E. S. and Wherry, E. T., Leverrierite from Colorado, Jour. Wash. Acad. Sci., VII, p. 208, 1917.

Ries, H., Clays, their occurrence, properties and uses, New York, 1927. Pp., 53-95 contain an excellent summary of the work done on the mineralogy of clays and an excellent bibliography is included.

Ross, C. S. and Kerr, P. F., The kaolinite minerals, U. S. Geol. Surv. Prof. Paper 165-E, p. 151, 1931.

Ross, C. S. and Shannon, E. V., The minerals of bentonite and related clays and their physical properties, Jour. Amer. Cer. Soc. IX, p. 77, 1926.
The chemical composition and optical properties of beidellite, Jour. Wash. Acad. Sci. XV, p. 467, 1925

Somers, R. E., Microscopic study of clays, U. S. Geol. Surv. Bull. 708, p. 292, 1922.

Properties of Clay

Types of clay in which the minerals are so closely matted together that it is difficult or impossible to separate them are low in plasticity. Such clays, even after fine grinding or a long period of stirring in water, are still seen under the microscope to be made up of granular aggregates rather than separated scales of the clay minerals. The plastic clays, on the other hand, break down very rapidly into separated particles. Plasticity is also reduced by the presence of quartz grains or other sandy material.

The color of clay is due largely to very minute particles of yellow or red iron oxide or dark particles of carbonaceous matter scattered through the clay aggregate. Greenish colors are due to the presence of shreds and scales of chlorite and related minerals. The color is, of course, greatly modified during burning and the final colors are chiefly due to the quantity of iron oxides and to the state of their oxidation.

The question of the burning qualities of a clay involve not only the chemical composition but also physical qualities such as fineness of grain, porosity, rate and method of burning, and other factors. In general it is very difficult to predict the burning qualities from a chemical analysis. Physical tests, including actual burning tests, are of much greater importance.

The clays found in this district vary from pure clays of the fire clay type down to the most impure siliceous and ferruginous types. They might be classified roughly as follows:

Classification of Shales and Clays

Paleozoic deposits	{	shales	{	pure clay-shale
			{	red
				green
				micaceous
				sandy
				black
	{	clays	{	fire clay
			{	flint clay
			{	semi-flint
				plastic
				red
				gray, calcareous
Alluvial clays	{	high terrace, plastic		
	{	flood plain, sandy and plastic		
Glacial clays		blue, plastic		

SHALE

The shales represent aggregates of clay minerals which, during deposition or through subsequent pressure, have taken on a lamination which permits them to be split into thin layers. The aggregates, in the case of the local shales, are broken down with difficulty so that they are only moderately plastic after fine grinding or long weathering. Many are weakly plastic and require the addition of surface soil or plastic clay to make them workable.

Pure clay-shales are generally of a light buff color. They have a slightly soapy feeling and when placed between the teeth gives no feeling of grit. Such shales are of high grade and may be used in making face brick, paving brick, and sewer pipe as well as common brick and tile. They generally burn to a red color, very few shales in this district being so free from iron that they will burn to lighter shades.

Red shales are present in the upper Permian of Greene County, in smaller amount in the Conemaugh group, and in large amounts in the Mauch Chunk series. These are a blood red color and may be free

from grit or may be quite sandy. Although very red, they are not too high in iron and burn into very good red brick.

Green shale may occur with the red or may lie in separate beds. It owes its color to ferrous iron compounds such as chloritic material, and is often as high in iron as the red shales. It, therefore, also burns red and is a useful source of brick and tile material.

Micaceous shale shows abundant finely divided scales of white mica on its lamination surfaces. This gives it very thin splitting qualities and lowers its coherence and plasticity to such an extent that it is of low or no value. Fortunately there is little of this type of shale in the district; in some places the shale above the Pittsburgh coal is micaceous.

Sandy shales comprise the greater portion of the shaly strata of western Pennsylvania. They range from a coarse gritty rock, practically a thin splitting impure sandstone, to a shale with only a small amount of grit. Sand in small amounts and finely divided is of no harm to a shale to be used in making brick. It reduces the shrinkage and forms a more open, porous body. If the sand content is excessive the plasticity is reduced so much that the ware cannot be molded or handled in the green state and will not burn to a firm body. The limits of sand allowable in a shale depend on the type of machinery used and the product desired. Some sandy shales are improved by adding soil, or a small amount of plastic fire clay.

Black shale high in carbonaceous matter is of no value to the clay worker. It commonly occurs in the roof of coal beds, and is known to the miner as "slate." Black shale is weakly plastic and its carbon content can be removed only by extremely slow burning. The carbon tends to give the brick a dark porous core or to cause a harmful swelling in the ware. Black shale is carefully avoided in quarrying.

PALEOZOIC CLAYS

Numerous beds of non-laminated, structureless clay are interbedded with the other strata of the Permian and Carboniferous periods. The purer types are generally below coal beds or beneath a carbonaceous streak which represents the horizon of a coal bed. These are termed "underclays." The less pure types are interbedded with the sandstones, shales and limestones and may underlie any of them. Why some of the clays deposited during the Carboniferous period have become shales while others have remained as clays is a problem. Also the question is still unsolved as to why some of the underclays are pure fire clay and others are ordinary impure clay.

The origin of fire clay has been discussed at length by many authors¹ but no agreement has been reached. There seems to be a close relation between the formation of the coal beds and that of the clay, and the clay seems to have been purified by some leaching process in the coal swamps. The writer believes that consideration should be given to the similarity in structure between fire clays, red clays and calcareous buff clays. All are without lamination, that is, they are structureless, and, unlike the clays deposited in earlier strata of the Paleozoic, they

¹ Hodson, F., The origin of bedded Pennsylvanian fire clays in the United States, Jour. Am. Ceramic Soc. v. 10, pp. 721-746, 1927.

Stout, W., Origin of coal formation clays, Ohio Geol. Surv. 4th Ser. Bull. 26, pp. 533-568, 1923.

Lovejoy, E., Notes on fire clays of the northern Appalachian coal basin, Jour. Am. Ceramic Soc. v. 2, pp. 374-390, 1919.

have not been transformed into shale. It would seem that the swamp waters of the Carboniferous brought about a colloidal precipitation of all three types of clay different from the ordinary sedimentation which produces shale.

Fire clays are practically pure hydrous aluminum silicates with little of the fluxing elements such as iron, calcium, magnesium, sodium, or potassium which lower the fusion point. Fire clays are refractory, that is, they fuse only at very high temperature. This property, coupled with proper shrinkage and porosity at certain burning temperatures, determines the quality of the fire clay. It may be classed as the best or No. 1, or may be rated as No. 2 or 3. The lower grades are made into fire brick not requiring high heat or can be used in making face brick or sewer pipe. The fire clays of this region are mostly underclays but the thickness of the overlying coal bears no relation to the thickness or quality of the clay. The normal plastic fire clay is light bluish gray, has a smooth soapy feeling, and may have smooth polished surfaces known as slickensides. These are due to movements in the clay mass. A frequent impurity is iron carbonate or iron sulphide in lumps or nodules scattered through the clay. These are very detrimental to the clay and must be removed if possible. Fire clay may grade downward into a very sandy clay, almost a sandstone at the base. The outcrop of a fire clay often is a bleached white clay which may give one a false idea of its quality.

Flint clay is a hard non-plastic fire clay which breaks with a smooth conchoidal fracture like flint or fine-grained limestone. It occurs as an underclay, either as a definite bed or as part of a bed of plastic fire clay. Often it is a lenticular mass in the plastic clay. It may be too siliceous or too ferruginous to be of value but usually it is a purer and more refractory clay than the plastic variety. Like the other fire clays it may carry detrimental nodules of the iron compounds but one has to be careful in condemning it because some nodules in flint clay are a highly aluminous compound, in part diaspore, which gives the clay a high refractory nature. It is difficult to judge the quality of a flint clay by visual examination. Flint clay is non-plastic and when used must be mixed with a plastic clay as a bond.

Semi-flint is an indefinite term given to some of the harder plastic fire clays which lie between flint and plastic clay in their appearance and qualities.

It should be said as a word of caution that all underclays are not fire clays although fire clay is the common miners' term for underclay. Many underclays are suitable only for manufacturing face brick.

Gray clays interbedded with the sandstone and limestones of the Carboniferous, especially in the Conemaugh group, are light colored and resemble fire clays in their crumbly structureless nature. These are usually very disappointing when tested because commonly they are high in lime and tend to fuse at a low temperature and very suddenly. Such clays are of no value. Some clays of this type, however, are of somewhat better grade and could be made into face brick and other products. Again the visual examination fails and their quality is determined only by a series of tests. Microscopic examination discloses no extraneous impurities. It is probable that their impurities, such as lime, have been absorbed into the clay substance and are therefore not removable.

Red clays form brilliant bands in the Mauch Chunk series, and the

so-called "Red beds" in the Conemaugh group. Some of the material is red shale but most of it is true clay. It is crumbly and structureless, mottled occasionally by patches of green clay or shale. It also may carry nodules of lime carbonate. This clay is quite plastic and is excellent material for the manufacture of red face brick and tile. Beds of it from 10 to 30 feet thick occur, as that just above the Birmingham shale which is extensively used in the Pittsburgh district for manufacturing face and common brick.

ALLUVIAL CLAYS

High terrace plastic clays 200 feet above the river in the vicinity of Pittsburgh and along the rivers to the south are known as the Carmichaels formation. Clays of similar origin are found on the terraces down the Ohio and Beaver rivers. When the ancient rivers which formed these terraces were more or less stagnant or ponded the deposits formed were fine-grained, yellow and gray clay which is extremely plastic. Unlike the older clays these are made up of non-aggregated clay particles and develop immediate plasticity after the manner of many surface residual clays. In earlier days they were used on the upper Monongahela River for the manufacture of stoneware and roofing tile, and tests made for this investigation indicate that they might also be used for making sewer pipe, paving brick, or face brick. At New Brighton they are used in making flower pots. They cover large areas but are irregular in their distribution and somewhat pockety, which of course is against their extensive use.

Flood plain clays are normal river muds and silts, very impure but usually fine grained and moderately plastic. They burn to a red color and make a satisfactory red common brick. At present they are not being used.

GLACIAL CLAYS

Glacial clays occur only in the northwestern counties. They are usually fine, bluish-gray, plastic clays carrying many boulders, but they weather to a yellow color in the surface layers. Although suitable for red common brick and tile, their greatest drawback is pockety distribution.

PHYSICAL TESTS

The laboratory tests of clays to determine their physical characteristics have been made in many government bureaus and private testing laboratories, and under the influence of the American Ceramic Society have become standardized. Tests on the clays of Pennsylvania are being conducted in the laboratories of the ceramic department of Pennsylvania State College under the direction of Prof. J. B. Shaw. His methods were discussed in Bulletin M10 of the Pennsylvania Geological Survey but it seems wise to describe them again in this report.

The clay is first ground and passed through a 20-mesh sieve. Water is then added to it until it is of the proper consistency for molding. A personal factor enters at this point but experience shows that workers judge the point of best plasticity very uniformly. From the feel the operator classifies the clay as of good, fair, or poor plasticity. The clay is then molded into bricks 1 by 1 by 2 inches in size and these are carefully weighed. Their volume is then determined in kerosene

in a volumeter. They are then dried to constant weight at 110° C. and weighed. The water lost is termed the "water of plasticity" and is calculated in percentage of the dry weight. It is the amount of water needed to bring the clay into a plastic state. Some authors prefer to call it the "tempering water." It varies from about 15 per cent up to 33 per cent in Pennsylvania clays. Water has no direct relation to the plasticity, or to the shrinkage of a clay but does in a measure reflect these properties. High water of plasticity usually indicates that a clay will have a high air shrinkage and a long slaking period. Twenty-three samples of Pennsylvania flint clays average 19.7 per cent water of plasticity, 6.6 per cent volume drying shrinkage, and 2.9 minutes of slaking. Twenty-two samples of No. 1 or No. 2 plastic fire clays in the State averaged 21.3 per cent water of plasticity, 13.5 per cent volume drying shrinkage, and 9.8 minutes of slaking. Five samples of the Carmichaels clay, a surface clay, averaged 32 per cent water of plasticity, 23.8 per cent volume drying shrinkage, and 12 minutes of slaking. These represent respectively clays of low, medium, and high plasticity and their relation in the three tests is striking. Other clays and shales are variable in quality but their water of plasticity will average around 22 per cent.

Shrinkage water. This is the amount of water which would be necessary to fill every pore of the dried briquette. In other words it represents the porosity of the briquette. It is calculated by the use of the following two formulae:

$$\text{Dry volume in cc.} = \frac{\text{Dry weight in grams}}{\text{Specific gravity}}$$

$$\text{Per cent shrinkage water} = \frac{\text{Wet volume in cc.} - \text{Dry volume in cc.} \times 100}{\text{Dry weight in grams}}$$

Pore water. This is the difference between the percentage of water of plasticity and the shrinkage water.

Drying shrinkage. The amount of shrinkage in a clay during drying may be measured and expressed in two ways, as linear shrinkage, and as volume shrinkage. Either may be determined and the other calculated or both may be determined as a check. Linear shrinkage is determined by molding a bar of clay 1 by 1 by 6 inches in size and making on the wet bar two marks 10 centimeters apart. The bar is then dried and the distance between the marks measured; the linear shrinkage is computed in per cent of the dry length. Volume shrinkage is determined by finding the wet volume of a molded block of clay, drying it, and then determining its volume when dry. These tests are made with the use of a volumeter. The shrinkage is stated in per cent of the dry volume. Formulae and tables have been devised for changing linear into volume shrinkage and vice versa but in this report both are given. Linear shrinkage is easier to determine but is apt to be less accurate.

Drying shrinkage varies from 2 up to 35 per cent in volume, the plastic clays usually showing a higher shrinkage than the lean ones. The addition of sand or grog to the clay will reduce its shrinkage. Sandy shales and clays therefore have low shrinkage. Flint clays

have a low volume shrinkage ranging from 1.5 to 13.9 per cent in the clays investigated. Plastic fire clays of No. 1 and No. 2 quality ranged from 1.4 to 23.1 per cent and averaged 13.5. Surface clays like the Carmichaels clay on the high river terraces ranged from 17.1 to 35 per cent in volume shrinkage and averaged 23.8.

Slaking. Some confusion consists in the use of the word slaking. Originally it was used to indicate the disintegration of clay when wholly or partly submerged in water. The test was applied to lumps of raw clay or shale. Some clays break down very quickly and others are not affected even after being submerged many days. This test gave the clay worker an idea of the ease by which the clay could be disintegrated at the plant or during a curing process.

Now, however, time of slaking refers to the number of minutes necessary to bring about the disintegration of a molded piece of clay immersed in water. There is no relation between the two types of slaking and this second test is applied as an indication of the plasticity of the clay, as it seems to be a simple and fairly good indication of that property. The test was made at the State College laboratory by molding two 1-inch cubes of clay, drying them at 110° C., placing them on a 4-mesh screen immersed in water to such a depth that the top of the cube was just out of water. The bottom of the cube was 1 inch above the bottom of the pan. The time necessary for the disintegration of the material so that it would fall through the screen was recorded in minutes as the time of slaking. Flint clays averaged 2.9 minutes, plastic fire clays 9.8 minutes, and very plastic surface clays 12 minutes. One very plastic surface clay, No. 100 from the terrace clays at Allenport, took two hours to disintegrate.

Modulus of rupture. This test determines the strength of the clay to resist rupture by direct pull. It has also been termed the tensile strength. It determines the green strength and in that way gives an idea as to the handling qualities of the brick while in the unburned state. The test is made by molding briquettes of clay in cement-testing molds, drying them at 110° C. and then pulling them apart in a standard cement-testing machine. The result is stated in pounds per square inch. Interpreted tests were made of the neat clay, of equal parts clay and sand, and of the clay burned at 1150° C. Plastic clays with a high drying shrinkage usually show a high green strength, while sandy clays, flint clays, and many kaolins have a very low modulus of rupture. Most of the clays tested showed a green strength between 100 and 300 pounds per square inch. Twenty-six per cent had a strength of less than 100 pounds; this included most of the flint clays and residual kaolins, and also a number of the poorer shales and a few plastic fire clays. Four per cent of the clays examined had a modulus of rupture of over 400 pounds. These included shales, plastic underclays, and surface clays. The highest strength found was 632 pounds in a surface clay near Hickory, Washington County.

BURNING TESTS

Tests to determine its burning or firing qualities are made on clay by burning air-dried pieces at various temperatures in a kiln. The clays of this investigation were burned to the following temperatures

in degrees Centigrade: 1000, 1050, 1100, 1150, 1200, 1250, 1300, 1350. The temperature of the kiln, either in the laboratory or in actual practice, is usually determined by a thermo-electric pyrometer which indicates the temperature on the dial of a galvanometer or records it on a revolving drum, or else by the use of pyrometric cones, known also as Seger cones. These cones are small pyramids so made of blended and graded clays and fluxes that they will fuse at certain definite temperatures. The number on a cone indicates that the cone will bend over when the temperature corresponding to that number is reached. The cones of interest in connection with the tests in this report are shown in the following table,¹ in which the cone number and its corresponding temperature value are given.

Table 2. Melting point of Orton standard pyrometric cones

No.	°C.	°F.	No.	°C.	°F.	No.	°C.	°F.
010	950	1742	5	1230	2246	19*	1510	2750
09	970	1778	6	1250	2282	20	1530	2786
08	990	1814	7	1270	2318	23	1590	2894
07	1010	1850	8	1290	2354	26*	1600	2912
06	1030	1886	9	1310	2390	27*	1620	2948
05	1050	1922	10	1330	2426	28*	1635	2975
04	1070	1958	11	1350	2462	29*	1650	3002
03	1090	1994	12	1370	2498	30*	1670	3038
02	1110	2030	13	1390	2534	31*	1685	3065
01	1130	2066	14	1410	2570	32*	1705	3101
1	1150	2102	15	1430	2606	33*	1720	3128
2	1170	2138	16	1450	2642	34*	1740	3164
3	1190	2174	17	1470	2678			
4	1210	2210	18	1490	2714			

* Corrected temperature from C. W. Kanolt, U. S. Bureau of Standards.

Like clays, the cones do not have a definite melting point and indicate only approximate temperature. However they do measure faithfully the effects of the heat upon the ware because they are undergoing the same changes as are the products being burned. By reference to the table above it will be seen that the temperatures used in our tests correspond to cones 07½, 05, 02½, 1, 3½, 6, 8½, and 11. The burned pieces at each temperature are studied as to color, hardness and tendencies to warp or crack. Determinations are then made of the shrinkage, porosity, and specific gravity of the test pieces.

Shrinkage. Shrinkage usually begins about cone 010 or 950° C. and increases as the temperature of the kiln is raised until a maximum is reached beyond which the brick begins to swell and deform. This point where swelling begins is termed the overburning point and is the danger line in clay burning. Clays very high in silica may swell before this point is reached, but ordinarily swelling and an increase in porosity indicate that the clay has reached its maximum burning temperature. The manner in which the clay shrinks during the burning is a very important indication of its value. It may shrink rapidly at first and then maintain a low but uniform shrinkage over a long range of temperatures; it may shrink at a uniform rate to a certain cone and then very suddenly swell or fuse; it may not shrink much until a very high temperature is reached. Such variations are best expressed by shrinkage curves.

Two definitions in regard to range of burning are given by Stull.²

¹ Coal formation clays, Geol. Survey of Ohio, 4th Ser., Bull. 26, p. 482, 1923.

² Stull, R. T., Coal formation clays: Geol. Survey of Ohio, 4th Ser., Bull. 26, p. 480, 1923.

Heat range he defines as "that range of temperature over which the the ware burned shows comparatively no difference in quality or appearance for one kind of product (as for example, paving brick)". That is, shrinkage and porosity would remain fairly constant over the heat range and their curves would flatten out. Burning range, also termed firing range, he defines as "that range of temperature over which the clay gives one or more different desirable products, as for example, very porous common brick, moderately porous face brick, and vitrified paving brick." In other words, the burning range represents the temperatures at which some kind of usable product may be made from the clay.

Shrinkage may be determined as linear or volume shrinkage expressed in per cent of the original size. Clays vary greatly in their shrinkage. Sandy clays and flint clays generally show a low shrinkage and more plastic clays a higher one. The range lies between practically no shrinkage up to 13 per cent linear or 34 per cent volume shrinkage. The following table gives some averages obtained in this investigation.

Table 3. Average burning, shrinkage, and fusion point of Pennsylvania clays.

	Per cent linear burning shrinkage	Cone of maxi- mum shrinkage	Cone of fusion
17 flint clays -----	4.9	3 (1190°C.)	31 (1685°C.)
19 plastic fire clays -----	5.7	4 (1210°C.)	29 (1650°C.)
52 shales used in brick making -----	6.7	2 (1170°C.)	11 (1350°C.)
73 shales, unused -----	7.1	01 (1130°C.)	12 (1370°C.)
63 plastic clays, underclays but not fire clays -----	5.7	2 (1170°C.)	19 (1530°C.)
9 surface clays -----	8.6	1½ (1160°C.)	14 (1410°C.)

Porosity. The amount of pore space in a brick is termed its porosity. This decreases as the shrinkage increases, but there is no exact relation between porosity and shrinkage and both are usually determined. They supplement each other. A brick is usually most porous at the end of the oxidation period in its burning, that is, after the water and other gases have been driven off and before any particles of the mass begin to fuse together. This point of greatest pore space is about cone 010 for most clays. As the temperature is increased from this point the pore space diminishes until complete vitrification is attained and the porosity drops almost to zero. The brick may continue at this stage over a long range of temperature, after which it swells and becomes porous again. This takes place at the point of overburning. The curve of porosity, like the curve of shrinkage, is very useful to the ceramist in judging the value of a clay. The porosity is determined by saturating the burned test piece in water, determining the weight of water absorbed, which in turn is converted into volume, 1 cc. of water weighing 1 gram. This is only the apparent porosity or the volume absorption, for saturation is never quite complete. For these tests the brick were boiled two hours in distilled water and then soaked in water for 24 hours. It should be noted that porosity is the volume of the spaces in the brick as compared to the volume of the entire brick; absorption is the weight of the absorbed water as compared to the weight of the dry brick.

In burning from cone 010 to cone 14, porosities decrease on the

average about as follows: flint clays from 37 to 31, plastic clays from 30 to 8, shales from 28 to 8.

Absorption. This is related to porosity as above stated and is determined from the same calculations. It should be termed apparent absorption because, as with porosity, the pores do not become completely saturated with water.

Specific gravity. Determinations of the specific gravity of a clay at different stages in its burning are of interest to the clay worker and a number of them have been made for this report. The specific gravity may be calculated and stated in three ways. First, as true specific gravity, which is the gravity of the particles exclusive of the pores; second, as apparent specific gravity, which is the specific gravity of the test piece including the pore space not saturated with water during soaking; and third, as bulk specific gravity, the gravity of the test piece taken as a whole mass with pore spaces included. True specific gravity, will, of course, be the greatest figure, apparent the next, and bulk specific gravity the lowest. One example would be a burned clay whose gravities were as follows: true 2.66, apparent 2.45, and bulk 2.29.

Fusion point. Clay is a mixture of various minerals, each with its own point of fusion, and therefore can have no definite point of melting or fusion. Parts of the mass begin to fuse at a comparatively low temperature and we say that the brick is in the stage of incipient vitrification. As the heat is increased the constituents continue to fuse together until the whole mass is vitrified. This stage is maintained for a longer or shorter period or heat range, after which the brick becomes so soft that it loses shape or swells. This point of deformation is the point the writer selects as the fusion point although some authors prefer to term it the softening point or the deformation point. With a cone, it is the point when the tip bends over and touches the base.

The fusion point is best determined by molding clay into small cones and actually fusing them in some type of high heat furnace, using Orton cones as a check on the temperature. Prof. Shaw uses a specially designed oxy-acetylene furnace for these determinations. Attempts have been made to calculate the fusion point of a clay from its chemical analysis but, on the whole, it is better to use the analysis only as a rough indication of fusibility, and use an actual fusion for the more accurate determination.

The clays examined in the State range in fusion point from cone 5 (1230°C.) up to cone 34 (1740°C.). As seen in Table 3 the average cones of fusion of the various types of clay were as follows; flint clay 31, plastic fire clay 29, plastic underclays other than fire clays 19, shales 12, and surface clays 14.

CHEMICAL ANALYSIS

The methods used in the quantitative analysis of clay have been thoroughly described in texts on analytical chemistry and are also given by Ries¹. The analysis usually includes the determination of the following substances: SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , CaO , MgO , K_2O , Na_2O and Ign. or loss on ignition. In addition, in some analyses

¹ Ries, H., Clays: Their occurrence, properties and uses. p. 105, 1927.

the amount of FeO is separated from Fe_2O_3 , and determinations are made of the amounts of MnO, P_2O_5 , and SO_3 . The loss on ignition is made up chiefly of combined water but of course includes such volatile constituents as CO_2 , SO_3 , and gases given off by organic matter.

The analyses of the clays discussed in this report were made by students in the chemical laboratories of Pennsylvania State College, under the direction of Prof. T. W. Mason. They were made in duplicate and carefully checked but may contain minor inaccuracies.

A pure clay should consist of one or more of the clay minerals without any extraneous matter or absorbed salts. If the clay mineral is one of the kaolinite group with a formula $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot 2\text{H}_2\text{O}$ the clay should contain 46 per cent SiO_2 , 39.5 per cent Al_2O_3 , and 14 per cent H_2O . Many china clays and fire clays approach this formula in purity. If, on the other hand, the clay mineral is beidellite, $(\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot n\text{H}_2\text{O})$, montmorillonite, or some other complex clay mineral, it might show quite different amounts of water, silica, or alumina and in addition might contain appreciable amounts of iron, calcium or magnesia.

Impure clays are those which, in addition to the clay mineral, contain grains or crystals of foreign matter such as quartz sand, pyrite crystals, small rods of rutile, nodules of limonite, particles of carbonaceous material, tiny rhombohedrons of calcite or siderite, and many other minerals. These appear in the analysis as impurities or excessive amounts of their respective elements.

Less information can be gleaned from the chemical analysis of a clay than from a series of physical tests, and in most instances a chemical analysis is unnecessary, especially of lower grade clays.

The following points may roughly be deduced by a study of a clay analysis:

1. An approach to the formula of kaolinite indicates a refractory clay.
2. High content of CaO, MgO, Na_2O , K_2O , or Fe_2O_3 indicates low fusibility.
3. Low iron content indicates that the clay will burn to a light color.
4. High iron content, if not accompanied by high lime, will burn red.
5. Al_2O_3 content over 40 per cent indicates high refractoriness.
6. SiO_2 over 60 per cent indicates a sandy clay.

Many attempts have been made to devise a formula whereby the refractoriness of a clay may be calculated from its chemical composition and some success has been achieved with the higher grade clays. In most cases, however, it is simpler, quicker, and cheaper to apply a direct fusion test.

REQUIREMENTS OF CLAY FOR VARIOUS TYPES OF CERAMIC PRODUCTS

From a study of the physical and chemical tests of clays given in this report and other publications, it is possible to decide the best uses for any particular clay or shale. The interpretation of the tests usually conforms closely to the results obtained in actual plant practice.

The clays described in this report come mainly under the following types.

Fire clays. For the manufacture of fire brick and other types of ware generally known as refractories, an increasing number of materials is used. Pennsylvania is a leading producer of the two most important, fire clay and silica sand. The sands of the State which can be used in making silica brick have been described elsewhere¹.

Clay suitable for the manufacture of any kind of refractory product is termed fire clay. This allows for a considerable range in quality, as refractories may be subject to low, moderate, or high heat, to considerable abrasion, to varied load, to the action of various slags or molten metals, or to the action of corrosive gases. For these various uses fire brick of varied types must be devised. This has given rise to the classification of fire clays into three grades known as Nos. 1, 2, and 3. This grading is based on their respective fusion points and their action during the gradual increase of firing temperature. The fusion point is of course a very necessary factor in the test of a fire clay but it must be supplemented by a careful study of the increasing shrinkage and specific gravity and the decreasing porosity during the burning of the clay.

No. 1 fire clays are those which fuse at cone 31 (1685°C. or 3065°F.) or above and whose porosity ranges from 27 to 31 per cent at cone 010 to 15 to 22 per cent at cone 11. In other words these clays have a slow, long range of decrease in porosity. Their best apparent burning range is from cone 6 to 15. Usually they are flint clays but they may be semi-flint or even plastic clays. Lack of plasticity and bonding power is corrected by adding a good plastic fire clay. Excessive shrinkage is overcome by adding a small quantity of crushed fire brick. The mixture is varied according to the conditions under which the product is to be used. Chemical analyses can be used only in a secondary way as an indication of the quality of a clay. In general a clay high in alumina and low in the main fluxing elements, Fe_2O_3 , TiO_2 , CaO , MgO , Na_2O , and K_2O is a high grade clay but so many factors enter into the fusing of a clay that interpretation by analysis is difficult. The physical tests are by far the most reliable guide to clay value. No. 1 clays are used almost exclusively for the manufacture of refractories because they are too valuable to use for other purposes and they require too high temperature to bring them to the density of other clay products.

No. 2 clays include all which fuse between cone 31, the lower limit for No. 1 clay and cone 26 (1600°C. or 2912°F.). They also show a gradual decrease in porosity from 27 to 31 per cent at cone 010 to 8 to 16 per cent at cone 11. Their curve of decreasing porosity falls more quickly than that of No. 1 clay and their best apparent burning range is from cone 5 to 10½. They are chiefly plastic fire clays and are used as a bond with the flint clays in the manufacture of refractories of moderate heat requirements, or in making lower grade products such as face brick, stoneware, terra cotta, and sewer pipe.

No. 3 clays include all which fuse from cone 26, the lower limit for No. 2 clays, down to cone 19 (1510°C. or 2750°F.) and whose porosity decreases fairly slowly and regularly from 27 to 31 per cent at cone

¹ Moore, E. S. and Taylor, T. G. The silica refractories of Pennsylvania, Pa. Geol. Surv., 4th ser., Bull. M3, 1924.

010 to 1 to 8 per cent at cone 11. They are usually burned at cone 2 to 8, and at these temperatures give products with porosities from 15 down to 3 per cent. They are used as bond in mixtures with the better fire clays, or are used alone for low heat duty refractories, or for the manufacture of buff face brick, sewer pipe, stoneware, hollow tile, and terra cotta.

It may be well to emphasize the fact that no fire clay can be recognized or graded by visual examination alone. A good plastic fire clay should be free from grit and excessive iron staining, and a good flint clay should break with a smooth curving or conchoidal fracture, but not even an expert attempts to judge a clay without a series of burning tests.

Sewer pipe clay. Sewer pipe are molded by forcing a stiff mud mixture through a die; the more complicated shapes are hand molded in plaster molds. The clay must necessarily be plastic and flow smoothly. Great care must be used in drying the ware so that it will not warp or crack, which means that the shrinkage of the clay must not be excessive. The ware is burned to the point of vitrification and it is desirable that this point be reached at not too high a temperature, usually between cones 5 and 10. The porosity may fall rapidly in burning so that it reaches $1\frac{1}{2}$ per cent at cone 02 in the lower grade clays but in this case the vitrification range should be long so that at cone 10 or higher there is no fusion. On the other hand, the porosity may remain high to cone 1 and then fall to the point of vitrification at about cone 7. Attention must also be given to the reaction of the clay to the salt glaze which is added during burning. Some clays react well and others give considerable trouble. Barringer¹ states that to take a good salt glaze a clay should have an alumina-silica ratio of 1-4.6 up to 1-12.5. Fire clay and shale are used in sewer pipe manufacture. If fire clay is used it must be the lower grades, Nos. 2 or 3, which vitrify at cone 9 or 10. If a shale or surface clay is used it must be above the general quality for these materials, as they generally do not vitrify at the right temperature or rate.

Paving brick clay. Paving brick must be burned to a vitrified state with a comparatively low but long burning range. This requires clay with a moderate amount of fluxes. It must also have good plasticity and tensile strength. The finished product should not show an absorption above 2 per cent and must be tough to resist abrasion and impact. A paving brick clay may remain very porous while burning until cone 1 is reached, when incipient vitrification then begins. Complete vitrification is attained at cone 5 and continues beyond cone 11. Shales are the most common material used. Low grade fire clays may be used, and sewer-pipe clays are very similar in their properties.

Stoneware clay. Stoneware of better grades, such as chemical stoneware, is made from low grade plastic fire clays; commoner grades, such as crocks, jugs and other household ware, can be made from very plastic surface clay. The main qualities are good plasticity, high tensile strength, and the burning to a dense body without excessive shrinkage. In some cases salt glaze is used and the body must react to this. Iron specks or other coarse particles are to be avoided. Stoneware made from fire clays is usually burned at cones 6 to 8.

¹ Barringer, L. E. The relation between the constitution of a clay and its ability to take a good salt glaze. Trans. Am. Ceramic Soc., vol. 4, pp. 211-229.

Terra cotta clay. This is generally a low grade fire clay which burns to a dense body at cones 6 to 8. It must have low shrinkage to avoid warping. Red-burning clays were formerly much used but on account of their iron content there was a tendency to overburn. Now the fire clays are preferred as they have a long range before overburning takes place.

Fireproofing and conduits are also made of low grade fire clays of about the same character as those used for sewer pipe and terra cotta. Their thin walls require that they have good drying qualities and will not warp.

Brick clays. Almost any type of clay or shale, after some experimentation or admixture of other ingredients, may be fashioned into building brick. For the more expensive, accurately molded and well colored face brick, the higher grades of brick clay are used. These grade up into No. 2 and 3 fire clays. Fire clays low in iron give a hard, dense body of uniform buff to gray color. These must be burned to about cone 8 and as they have a long burning range there is little danger of overburning. Buff face brick can also be made from calcareous clays but there is great danger of over burning as such clays have a very short range between incipient vitrification and viscosity. Red face brick are made from clays with a moderate iron content and a low amount of lime. They can be burned to a satisfactory body at a much lower temperature than the fire clays. Face brick clays must be plastic and smooth working and above all must burn to a uniform and pleasing color. Most shales which are not too sandy or limy will make good face brick. Some have low plasticity and green strength but can be improved by allowing some of the surface soil in the quarry to mix with the shale. Some quarries also have thin fire clay layers which are added to the mixture.

Lower grades of clay or shale which burn to a firm body at temperatures as low as cones 010 to 02 are useful in the manufacture of common brick, back-up brick, chimney brick, and drain tile. These clays generally burn to a red color, may vary considerably in their sand content, and make a product with a wide range in porosity, strength, and color. For economy, they must burn to a usable body at a low temperature and must not fuse too suddenly. Generally they are molded in a stiff-mud machine and therefore must have a plastic character and a reasonable green strength. These qualities are often low in the shales of Pennsylvania but with the usual mode of quarrying, a mixture of various shales and surface soil furnishes a workable clay.

It is thus possible, from a study of the physical tests, to arrive at an approximate conclusion as to the use of any clay or shale. The figures for plasticity and green strength (modulus of rupture) give an idea regarding the working and handling qualities before burning; the drying shrinkage indicates the amount of danger from warping and cracking, the density of the dried product, and of course the loss in size from that of the original mold. It does not indicate the rate at which a clay can be dried. Some dry easily and others have to be dried with great care and very slowly. A study of the shrinkage, porosity, and specific gravity of the burned clay at various temperatures indicates its burning qualities and will, in great measure, determine its use.

DESCRIPTION BY COUNTIES

ALLEGHENY COUNTY

Allegheny County is bordered by Washington County on the south, by Beaver and Washington counties on the west, by Butler County on the north, and by Westmoreland County on the east. Its surface is a hilly upland, deeply dissected by four large rivers and a number of smaller streams. The highlands average around 1200 feet above sea level and are parts of the peneplain generally called the Harrisburg peneplain. A few hills rise above this peneplain level. A second erosion stage is indicated by a series of levels at about 1100 feet above the sea and these are considered parts of the Worthington peneplain. Along the main river valleys there are also several elevated terraces representing stages in the development of the rivers. Of these the most prominent are a series of terraces and old river channels about 200 feet above the present streams or about 900 feet above the sea. These rock terraces along the Allegheny and Ohio rivers are covered with sands, clays and gravels of glacial origin, deposited during an early part of the Glacial period, perhaps during the Illinoian ice advance. Similar terraces along the Monongahela and Youghiogheny rivers are covered with sands, clays and gravels of local origin deposited at the same time as the others. These deposits are known as the Carmichaels deposits.

The dominating feature of the topography of the county is the radiating arrangement of the principal rivers which unite at Pittsburgh. Allegheny River comes in from the northeast, Monongahela River from the south, these uniting to form the Ohio River which flows northwest. These great valleys are 500 feet deep and form the main highways for water and rail transportation. Along them the industrial development is intense, while the uplands are given over to residential or agricultural development.

The rocks of the county range from the Washington group in the southern hilltops, down through the Monongahela and Conemaugh groups and into the upper Allegheny group exposed in a few areas in the northern half of the county.

Thickness of strata exposed in Allegheny County

Group	Feet
Washington (lower)	200
Monongahela	340
Conemaugh	600
Allegheny (upper)	140

In addition to these bed rocks, unconsolidated rocks such as sands, gravels, and clays are found upon rock terraces along the main streams, as mentioned in a previous paragraph.

The shales and clays of the Carboniferous period have been extensively developed throughout the county and the Carmichaels deposits to a lesser degree. Very little fire clay occurs in the county and none is being mined.

The county is well served with railroads, branches of the Pennsyl-

vania, the Baltimore & Ohio, the Buffalo, Rochester & Pittsburgh, the Pittsburgh & Lake Erie, and the Bessemer & Lake Erie following most of the valleys of the county.

The arrangement of the rivers divides the county into three main divisions, the northern region, between the Ohio and Allegheny rivers; the western region, west of the Ohio and Monongahela rivers, and the eastern region, between the Allegheny and Monongahela rivers. These three upland areas will be discussed separately and the development along each of the main river valleys also described as separate units.

ALLEGHENY VALLEY

The Allegheny River from Freeport down to Pittsburgh has cut a deep valley in the Conemaugh and upper Allegheny strata, making them accessible for development along the branches of the Pennsylvania Railroad which follow both banks.

From Freeport down the river to Hites Station the strata immediately along the river and railroad are of upper Allegheny age, with

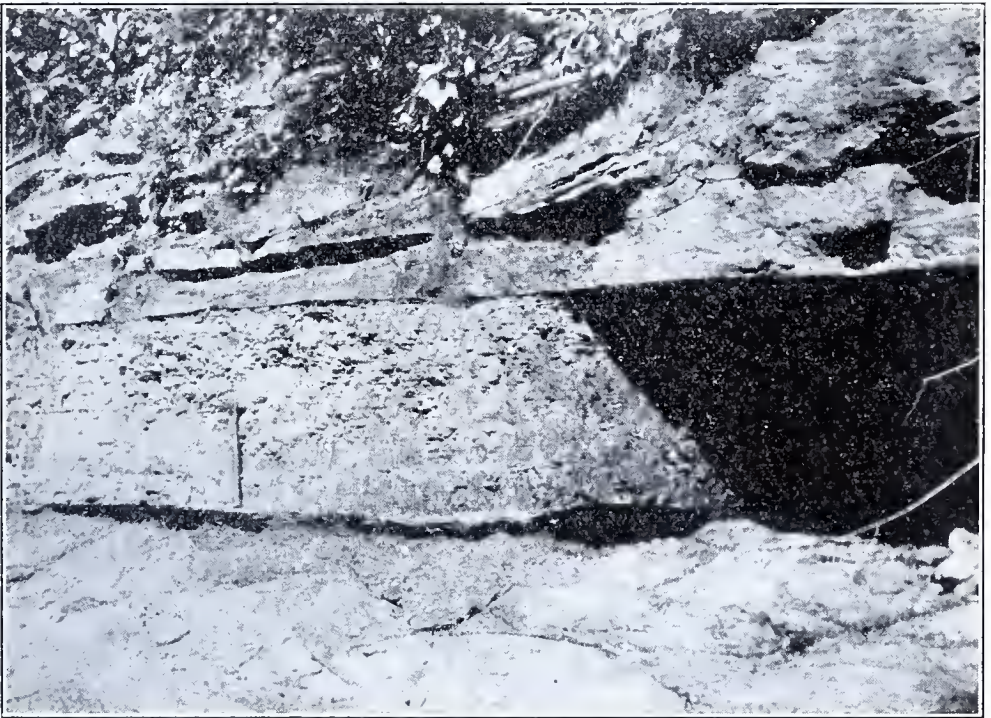


Fig. 1. Upper Freeport coal and underclay

the Upper Freeport coal 140 feet above the river at Freeport, 80 feet above at Tarentum and at river level below Hites. Above Creighton the Allegheny group generally shows an Upper Freeport coal about 3 feet thick (Fig. 1), a thinner Lower Freeport coal 60 feet below, the interval between being filled with shales, sandstones and fresh-water limestones. Below the coals there may be thin fire clays 1 to 3 feet thick but none have been noted of sufficient purity or thickness to be of any value. Sample 116 (see Westmoreland County) would indicate that the Freeport clays might be used around Freeport for the manufacture of buff brick if thick enough for development.

Good shales are not found in this region below the Freeport horizons because the limestones, thin coals, and sandstones interfere, or the shales are too dark or sandy.

As the Upper Freeport coal falls toward river level, the lower part of the Conemaugh group becomes accessible and it has been extensively used for making brick between Natrona and Harmarville. The section of the lower Conemaugh exposed in this region appears somewhat as follows:

Section of lower Conemaugh group below Natrona.

	Feet
Thin-bedded, gray shales	15
Pine Creek limestone	2
Sandy shales	25
Shales and sandstones	20
Thin, gray, jointed shale	10—15
Brush Creek limestone	1
Dark shale	15
Brush Creek coal	0— $\frac{1}{2}$
Clay, gray, purple, sometimes with lime nodules	6
Sandstone or shale	30—40
Upper Freeport coal	

The shales above the Pine Creek limestone (see Figs. 2 and 3) are represented by samples 131 and 132. Sample 131 was collected on Powers Run near its mouth. It develops poor plasticity and has low green strength. It fires to light red or reddish brown and has a firing range of 1000 to 1200°C. It could not well be used alone but could be used mixed with surface clays which would tend to increase its plasticity.

Sample 132 was obtained at Harmarville from the quarry of the Kountz Brothers Company brickyard, long abandoned. This shale showed fair plasticity but low green strength. It fired to light to dark red with a firing range of 1000 to 1150°C. It seems suitable for making red face brick and drain tile.



Fig. 2. Pine Creek limestone north of Parnassus

These tests indicate that the shale above the Pine Creek limestone is sandy and short and can be used successfully only in conjunction with some more plastic shale or clay. Shales at this horizon were formerly used by Kountz Brothers at Harmarville and by the Blatchford Meeds Brick Company at Barking. These firms are not now operating.

Shales above and below the Brush Creek limestone are used by the Martin Brick and Paving Company at Hites and by the McFetridge Brothers Brick Company at Creighton. Sample 151 is the ground shale used by the Martin plant at Hites. It has good plasticity and fair green strength and fires to light red or dark brown. Its burning range is from 1000 to 1200° C. It is an excellent material for the manufacture of face brick, common brick, and drain tile.

Sample 152 represents the 15 feet of dark shale just below the Brush Creek limestone in the McFetridge quarry at Creighton.

Section at the McFetridge quarry, Creighton.

	Feet
Shale and sandstone to hilltop	10
Fine, dark, jointed shale (used)	15
Brush Creek limestone, very fossiliferous	1
Thin dark shale, sample 152	15
Coal	½
Gray clay with nodular limestone	6
Sandstone and shale	25
Upper Freeport coal	8
Coarse sandstone	2
Nodular sandstone and shale	8
Gray clay	3
Fresh-water limestone	1
Shale and sandstone	8
Clay	1
Sandstone to level of plant	8

The shale tested showed fair plasticity but low green strength. It burned to pink to dark red and had a burning range of 1000 to 1200°C. It was found suitable for the manufacture of face brick, common brick and drain tile. However, it does not seem to be as good as the shale above, which they are now using. The 6-foot bed of gray clay might also be used to advantage to give greater plasticity or it is possible that with a little experimentation this clay might be used alone for a lighter colored brick. The shale is trammed to the plant by mules, passed through an auger machine, and burned in a battery of five rectangular kilns. The chief product is red face brick of good quality.

The clay at the McFetridge and Martin plants is apt to contain lime or iron nodules, but at Freeport it is of better grade and is made into refractory products. If not too badly contaminated with these nodules it is usually somewhat refractory. The Martin plant uses this clay in their mixture and the quality of the product is no doubt improved thereby. This clay is a persistent bed over many counties in western Pennsylvania. It ranges from 5 to 20 feet thick and is frequently utilized.

From Powers Run down to Pittsburgh the strata continue to descend

so that the higher beds of the Conemaugh group are exposed. The interval of 125 feet between the Pine Creek and Ames limestones carries chiefly sandstones and sandy shales and there seems little chance for shale development until the Pittsburgh city line is reached.



Fig. 3. Pine Creek limestone near Parnassus.



Fig. 4. Brilliant cut, Pittsburgh, showing red shales overlying Ames limestone.

Here the Ames limestone lies only a few feet above the railroad and there is ample opportunity to develop the red beds above and below it (See Fig. 4.). At Sharpsburg these beds were once used for making brick. In the old quarry the following section is exposed:

Section in quarry at Sharpsburg.

	Feet
Birmingham shale, blue	20
Greenish clay	5
Red clay with lime nodules	2
Greenish sandstone and shale	15
Ames limestone, fossiliferous	2
Red clay	10
Heavy sandstone	2
Sandy shale	10
Thin blue shale	8

When operating, the brick plant used practically everything above the 2-foot layer of sandstone but the greater part of the mixture was no doubt the red and green beds just under the Ames limestone. Elsewhere these beds have proven to be excellent for the manufacture of face brick (see tests on samples 104, 107 and 126). Good shales or red clays can be obtained from track level up to 100 or 150 feet above the railroad (See Fig. 10) and face brick, fireproofing, and perhaps even sewer pipe could be manufactured.

The terrace and alluvial material along the river is of little importance to the brick manufacturer. The upper terraces, 200 feet above the river, are generally covered with glacial gravels and the lower terraces with gravels or fine yellow silts. Some of the alluvial material along the river banks was formerly used for making brick but its use has been long discontinued.

NORTHERN ALLEGHENY COUNTY

The townships between the Allegheny and Ohio rivers form an upland largely given over to farming and residential uses. They are drained by many short streams which enter Ohio River, and by Pine Creek and Powers Run, Bull Creek, and other smaller streams tributary to Allegheny River.

The area is traversed by the Baltimore & Ohio Railroad which follows Pine Creek to the Butler County line near Valencia, and by the Bessemer & Lake Erie Railroad which follows Little Deer Creek Valley through Russelton and Culmerville.

The strata exposed in this area are all of Conemaugh age with the exception of a few high knobs capped by the Pittsburgh coal and two areas of upper Allegheny rocks, one centering around Allison Park and the other along Bull Creek.

Allegheny group. At Tarentum 80 feet of the Allegheny group are exposed. Included in the section is the Upper Freeport coal 3½ feet thick, its underclay 3 to 4 feet thick, sandy shales and fresh-water limestone. In Big Bull Creek valley the Upper Freeport coal rises rapidly so that at the mouth of Little Bull Creek it is 130 feet above stream level. The Lower Freeport coal is 60 feet below, the interval being occupied by shales, sandstones, and limestones. Thence up the stream for 2 miles the upper portion of the Allegheny group is exposed. Above that point the strata dip northwest and the Upper Freeport coal dips beneath the stream. This dip continues through Millers-town with the Brush Creek coal and an underlying clay as the surface strata. North of Millers-town the Upper Freeport coal reappears near the Butler County line. The only stratum of value in the series would

be the clay beneath the Upper Freeport coal. This appears to be a soft blue clay three to four feet thick. Mined with the overlying coal it might be utilized in the manufacture of face brick, sewer pipe, and fireproofing.

The second area of Allegheny strata extends from a point north of Glenshaw to Allison Park and Gourdhead Run. It lies on the crest of the Pine Creek anticline and the deep valley has exposed about 30 feet of the upper beds of the Allegheny group. On the Baltimore & Ohio Railroad at Allison Park a section is exposed as follows:

Section of Allegheny strata at Allison Park

	Feet	Inches
Sandstone	6	
Coal (Upper Freeport)	0	6
Fire clay	3	
Limestone (in 3 layers)	10	
Shale	4	
Sandstone	1	
Light gray shale	5	
Coal (Lower Freeport)	0	6
Clay (sample 154)	5	
Sandy clay	1	6

The two thin coals probably represent the Freeport beds. Each is underlain with clay of possible value. The lower clay in the tests showed good plasticity and low green strength. It burned to a cream to buff color and had an excellent firing range of 1100 to 1300°C. It fused at cone 27 or 1605°C. It could no doubt be successfully used in the manufacture of face brick, sewer pipe, and fireproofing, and with a moderately high fusion point might also make low duty refractory products. These clays are in an excellent location for development and deserve consideration. One mile north of Allison Park along Gourdhead Run the upper coal thins out to a mere streak and the lower one thickens to three feet and has been mined. No clay of importance was noted at this point under these coals, but clay occurs at the Brush Creek horizon above.

Conemaugh group. With the exception of the small areas of Allegheny strata just described and the few knobs showing Pittsburgh coal the northern part of the county has for its surface rocks the Conemaugh group. The strata below the Ames limestone are most frequently exposed. This part of the Conemaugh group carries three great sandstone members, the Saltsburg, the Buffalo, and the Mahoning, which, although not always massive, are generally too sandy to be considered as sources of brick materials. However, above and below the Pine Creek and the Brush Creek limestones there are shales of value and also some so-called fire clays which, although not very refractory, could be used to advantage in making face brick and sewer pipe.

The Brush Creek coal and limestone lie 70 to 110 feet above the Upper Freeport coal. Along Allegheny River and Pine Creek the interval shows little Mahoning sandstone but is generally occupied by shale and often contains one or more beds of semi-refractory clay. This is the clay which is utilized at Hites, Creighton, and Freeport. Its relation to the Brush Creek coal and limestone is not always the same. In some places the clay bed seems more properly to belong to the

Mahoning horizon, as in the case of the Gourdhead clay along Gourdhead Run. At any rate we may expect to find a valuable clay 6 to 15 feet thick at this general horizon. Sample 155 represents a 6-foot bed of clay at this horizon along Gourdhead Run. It developed fair plasticity and showed low green strength. It fired to red to dark red, with a firing range of 1050 to 1200°C. It seems suitable for face brick and fireproofing.

A similar clay and probably of the same horizon outcrops under the high bridge at Emsworth. The tests on this clay (No. 157) show it to have fair plasticity, low green strength. It fires to dark red with a firing range of 1050 to 1200°C. From it could be made face brick, paving brick, sewer pipe, and drain tile.

Just west of Talleycavey a 4-foot bed of clay very similar in its properties to the two just described is exposed. This lies a few feet below the Pine Creek limestone, a position in which clay is seldom seen. Sample 156 represents this clay. This shows fair plasticity and green strength, a burned color of dark red, and a firing range of 1000 to 1200°C. It seems suitable for making face brick, fireproofing, sewer pipe, and drain tile.

The interval between the Brush Creek and Pine Creek limestones is about 60 feet and is usually filled with bluish-gray shales. These shales are generally of low plasticity and are not of any great value for brick making. The Wittmer Brick Company formerly used this shale at Wittmer Station and sample 130 is from that quarry. It developed fair plasticity, with low green strength, and fired to a light red to reddish brown with a firing range of 1000 to 1200°C. Prof. Shaw think it of little practical value. Shales in this interval are common along the railroad cuts in the northern townships and no doubt they could be utilized for making red brick if mixed with weathered surface shale or soil.

Just above the Pine Creek limestone similar bluish shales occur and these also have been used in former years by the Wittmer Brick Company. They have the same general properties as those below the limestone. Sample 129 taken at Wittmer indicates that this shale has fair plasticity, very low green strength, and that it fires to light red to brownish red with a firing range of 1000 to 1200°C. It is of somewhat better grade than the lower material and could be used for making face brick. Shale at this horizon is abundant and, although somewhat "short," could be made into red brick, especially if weathered shale were added to the mixture.

The interval of 125 feet between the Pine Creek and Ames limestones carries no beds of shale or clay of interest except the clay beds just below the Ames limestone. In the interval lies the Woods Run limestone and the Bakerstown coal bed. No clay of value accompanies this coal. A great deal of the interval is taken up by massive and thin-bedded sandstones.

The red, vari-colored, or greenish clays which underlie the Ames limestone are exposed on the higher hills in the southern part of the northern area. They are very plastic and in other sections have been used successfully in making brick. Their chief drawback is the tendency to be somewhat calcareous and therefore to have a short firing range and a rather sudden fusion point. The northern townships contain only small areas of rocks above the Ames limestone. A few high knobs in Pine Township, on the east border of Franklin Town-

ship, and in Ohio Township show small outcrops of Pittsburgh coal and around them there must of course be upper Conemaugh strata. Over the main part of the region, however, and especially that portion traversed by the Bessemer & Lake Erie Railroad and the Baltimore & Ohio Railroad the exposed strata are of lower Conemaugh age and are chiefly bluish-gray, thin-splitting shales of poor or medium quality.

OHIO RIVER VALLEY

From the "Point" in Pittsburgh, down Ohio River to the border of Beaver County the Pennsylvania and the Pittsburgh & Lake Erie railroads follow the banks and along them are many fine exposures of the upper, middle and lower divisions of the Conemaugh strata. The Ames limestone, the dividing line between the lower and upper divisions of the Conemaugh, is 250 to 300 feet above the river and is therefore found only on the higher cliffs or back in the many deep ravines, such as Spruce and Lowries runs. The available strata along the Ohio valley are thus some 300 feet of lower Conemaugh rocks, the river not cutting quite low enough to expose the Freeport coal.

Although many variations in character and thickness occur in these strata a general section for the region might be shown as follows:

Section of lower Conemaugh group on Ohio River.

	Feet	Inches
Bakerstown coal	0	6
Fire clay	1	6
Shales	20	
Pine Creek limestone	2	
Shales	10	
Buffalo sandstone	35	
Shale	15	
Brush Creek limestone	1	
Shale	6	
Brush Creek coal	1	
Dark shale	10	
Upper Mahoning sandstone	40	
Mahoning shale, coal, and clay	15	
Lower Mahoning sandstone	40	

Near track level the chief exposures are the Upper Mahoning sandstone with the shale and clay layer beneath. The clay in this zone may be a 5- to 10-foot bed of bluish fire clay similar to sample 127 taken at Fair Oaks. This fired to light buff with a firing range of 1000 to 1200°C. but developed poor plasticity and is not believed to be of much value.

At other places at this horizon there is often seen a flint-like clay. A sample (No. 158) was taken of this clay along the road opposite Ambridge. Here under the Upper Mahoning sandstone there appears 5 feet of soft clay similar to sample 127 and beneath it 8 feet of brownish flint clay. This clay (No. 158) showed fair plasticity and green strength and fired to dark buff with a range of 1100 to 1300°C. Its fusion point was cone 20 or 2786° F. which is low for a fire clay and the material is not considered of much value. It would seem therefore that the clays at this horizon, although they often look valuable, are not of very good quality.

Beneath the Brush Creek coal there is usually a bed of bluish-black clay or shale 10 to 15 feet thick. From an exposure of this clay op-

posite Sewickley and just north of the bridge, sample 128 was collected. The bed sampled was 7 feet thick. This clay shows good plasticity, fires to a salmon or tan color with a firing range of 1000 to 1150°C. The burned color was not very good but aside from this it could be made into satisfactory face brick.

Formerly a brick yard in operation one mile east of Shousetown on the Pittsburgh & Lake Erie Railroad used a mixture of shale overlying the Brush Creek limestone and the clay below the Brush Creek coal.

Under the high bridge on the Lowries Run road east of Emsworth there is a 5-foot bed of clay underlying 13 feet of shale. This may be in the Brush Creek horizon. Sample 157 shows it to have fair plasticity, low green strength, and to fire to red with a range of 1050 to 1200°C. It seems well adapted to the manufacture of face brick, paving brick, sewer pipe, and drain tile. It could be used alone or in conjunction with the overlying shales.

Brick are not now made along Ohio River in Allegheny County. In earlier days the plant of the Pittsburgh Brick Company near Shousetown (at Briggstown) was producing red brick from shale and clay while two companies at Leetsdale, the Penn Brick Company and the Harmony Brick Company, were making common brick from the soft alluvial clays along the river banks.

EASTERN ALLEGHENY COUNTY

This region, between the Allegheny and the Monongahela rivers, includes the main part of Pittsburgh, its East End section, Wilkinsburg, Edgewood, Swissvale, and the territory to the east. It is chiefly a highland rising 300 to 500 feet above the rivers. In the lower parts of the city along the rivers the exposed strata are those just above or below the Ames limestone. Farther from the rivers in the higher lands the strata seen are the shales and clays of the upper Conemaugh group and those above the Pittsburgh coal, which lies near the hill-tops. The Pennsylvania Railroad and the Baltimore & Ohio Railroad pass through this eastern part of the city and in their cuts the strata from the Morgantown sandstone down to the red beds above and below the Ames limestone are well exposed. Shales and red clays could be developed along these railroads but in most cases the land is too valuable for other purposes. From Oakland through East Liberty, Wilkinsburg, and Edgewood the chief topographic feature is a broad flat valley, a former channel of the ancient Monongahela River. This valley bottom is covered with clays and sands of the Carmichaels formation to a depth up to 50 feet. In earlier times the clay portion of these deposits was used in the manufacture of common brick at many localities in the East End but with the increase in land values and the discovery that shales make a better product the yards were abandoned.

The greater part of the between-rivers area lies above the Morgantown sandstone, and the higher hills rise 50 to 75 feet above the Pittsburgh coal. This has made possible the location of brick yards without rail connections throughout the East End, and a number of such yards are in operation between the business section of Pittsburgh and the borough of Wilkinsburg.

From the downtown section eastward these are as follows:

The Booth & Flinn Company yard lies north of Fifth Avenue on

a high hill between Dinwiddie and Soho streets. In the quarry the following section is exposed:

Section in Booth & Flinn Company quarry, Pittsburgh

	Feet
Yellowish sandstone and shale	10
Pittsburgh coal	5
Nodular gray limestone	1½
Shale	6
Limestone	2
Shale	1
Limestone	1
Shale with limestone layers and some red shale ...	20

The shale used is the lower layer with what falls from the beds up to the Pittsburgh coal. This necessitates careful sorting out of the limestone and sandstone blocks. A ground sample (No. 147) of the material used showed good plasticity, fair green strength, a fired color of light to dark red, and a firing range of 1000 to 1200°C. It fused at cone 5 or 2201°F. It is suitable for making red face brick, common brick, and drain tile. The shale is quarried with a steam shovel, carried to the plant with electric tram, ground in a dry pan, and molded with a Freese auger machine. The brick are burned in coal-fired scove kilns. Shipment is made by truck. The product is face and common brick and the plant has been in operation since 1910.

The Central Brick Company formerly operated a plant east of the Booth & Flynn plant on the hill east of Soho Street but it is now dismantled. Shales of about the same horizon as those of the Booth & Flynn quarry were used.

The Entress Brick Company plant is at Bedford and Duff streets and the quarry is two blocks east at Junilla Street and Bedford Avenue. The shale used is a bed of smooth olive-colored material just above the level of Bedford Avenue in a bench about 15 feet thick. The horizon of the shale seems to be between the Pittsburgh and Red-stone coals. This material (No. 146) showed fair plasticity, very low green strength, a firing color light red to dark red, and a firing range of 1000 to 1200°C. It seems suitable for the manufacture of face brick, common brick, and drain tile. The plant uses an auger machine and burns the brick in scove kilns, fired with gas. Shipment is made by truck.

The Iron City Brick and Stone Company is located at Stanton and McCandless streets 1½ miles northwest of East Liberty.

Section at Iron City Co. quarry.

	Feet
Sandy shale and sandstone	10
Yellow shale	10
Limestone	1
Red and vari-colored clays	3—30
Massive greenish sandstone	15

The lower sandstone is probably the Connellsville bed. Formerly the company used the upper shales but street development stopped their use and now they are using the thicker portion of the red beds in the west end of the quarry. Sample 145 of this clay showed good plasticity and low green strength. It burned to light or dark red with a

firing range of 1050 to 1150°C. It fused at cone 7 or 2282°F.* These tests indicate that this clay could be used in making face and common brick, and drain tile. The plant is equipped with dry pan, auger machine, tunnel driers, and three square kilns. A coal-fired continuous kiln was formerly used but on account of the smoke nuisance in a residential district the use of coal was discontinued and the brick are now fired with gas in the rectangular type of kiln.

The brick yard of the Gough Brick and Tile Co. is located at Paulson and Nelson streets, two miles east of East Liberty. The section in their quarry is as follows:

Section in Gough Company quarry.

	Feet
Buff shale	3
Dark and purple shale	1
Olive shale	2
Red shale	10
Red clay	2
Sandy and olive shales	6
Red clay	3
Sandy shale	0—3
Red shale	10
Heavy sandstone	20

These rocks lie below the Pittsburgh coal in the upper part of the Conemaugh group. The upper four members are used in making brick and sample 139 is from a mixture of these beds. This gives good plasticity and fair green strength. It fires to light to dark red, and has a firing range of 1000 to 1200°C. It is suitable for making red face brick, and hollow tile. The shale is quarried with a steam shovel, ground in a dry pan, and molded in a Freese auger machine. It is burned in scove kilns fired with producer-gas made at the plant.

John Ward and Sons operate a brick yard at Oakwood and Batavia streets, half a mile north of Wilkinsburg. The quarry shows the following section:

Section at Ward quarry, Wilkinsburg.

	Feet
Shaly sandstone	10
Crumbly clay	6
Brown sandy shale	8
Dark shale (Little Clarksburg)	2
Limy nodular masses	1
Crumbly clay	25
Heavy sandstone (Morgantown)	10

The company has used the upper clay and shales successfully and also the clay just above the Morgantown sandstone. The latter (sample 135) shows fair plasticity and low green strength. It fired to medium or dark red, and had a burning range of 1000 to 1150°C. It fused at cone 11 or 2417°F. It can be used for the manufacture of face brick, common brick and drain tile.

Hooper Brothers formerly operated a brick yard on Blackadore Street 1½ miles north of Wilkinsburg. After operating from 1890

* The cone temperatures reported by Prof. Shaw in Table 24 and quoted in this part of the text do not agree with the temperatures of standard cones as recorded in Table 2. Variation in the fusion point of cones is to be expected, however.

to 1928 the plant burned down and the owners do not intend to rebuild. The section exposed at the yard is as follows:

Section at Hooper quarry, north of Wilkinsburg

	Feet
Limestone	2
Clay with lime nodules	6
Sandstone	1
Shales, thin red at the base	10
Purple clay	2
Thin coaly streak	
Purple clay	1½
Olive shale	4
Yellow sandy shales	5

The material used was either the upper four members, eliminating the limestone, or the lower five members which were less limy. The beds lie a short distance below the Pittsburgh coal. Sample 136 is from the 10-foot layer of shale. It develops fair plasticity, has fair green strength, and fires to a light or dark red with a firing range of 1000 to 1200° C. It fuses at cone 13 or 2462° F. It seems suitable for face brick. Sample 137 represents the purple clays in the lower terrace. This material has good plasticity and fair green strength. It burns to salmon or dark brown with a firing range of 1000 to 1200° C. It fuses at cone 15 or 2615° F. It should make satisfactory red face brick, drain tile, and fireproofing.

The Milliken Brick Company has recently built a brick plant near the junction of Laketon Road and Montier Street in Wilkinsburg, along the Verona trolley line. The quarry is in the shales resting upon the Pittsburgh coal, this coal forming the bottom of the quarry. The shale is 20 to 30 feet thick and shows occasional lenses of sandstone which are discarded. At the top of the quarry the shale grades into yellowish decomposed shale and soil. Sample 133 represents the crude shale from the quarry. It shows fair plasticity and low green strength. It fires to a buff to gray-brown color with a firing range of 1000 to 1200° C, and fuses at cone 12 or 2435° F. Sample 134 represents the ground material in use in the plant. As seen from the tests it has a slightly higher firing range and fusion point, due probably to a greater admixture of sandy material or surface soil. Both samples indicate that the shale is an excellent material for face brick manufacture and this is the use now made of it. The plant is equipped with roll crusher and dry pan, a Freese auger machine, drying tunnels, 6 down-draft rectangular kilns. Red face and common brick are made. Shipments are by truck.

From a description of these numerous yards it can be seen that the city in its area between the rivers, is well supplied with brick making materials. These range from the shales above the Pittsburgh coal down to the red clays of the Ames horizon. In seeking a location for a brick yard not only must the quality of the shale or clay be considered, but in the city one must also find a location where city development will not too soon encroach upon the plant and where smoke will not be an annoyance to the neighborhood. These problems are making it increasingly difficult to maintain plants within the city limits.

The eastern townships. The area east of Wilkinsburg and between Allegheny River and Turtle Creek is a high, hilly region crossed by

the Bessemer & Lake Erie Railroad and by the William Penn Highway. The higher lands contain workable amounts of the Pittsburgh coal and the lower valleys expose the Ames limestone, and on the extreme eastern edge of the county, the Pine Creek limestone. There is, therefore, opportunity to quarry brick shales or clays from horizons above the Pittsburgh coal or from the upper two-thirds of the Conemaugh group.

The only sample taken in the region was of the shale just above the Woods Run limestone, exposed near Abers Creek on the William Penn Highway. This (No. 235) is seen from the tests to have fair plasticity and good green strength. It burns to a red color with a firing range from 900 to 1000° C. It seems suitable for face brick manufacture. Similar shales between the Pine Creek and Ames limestones should be found along Pucketa and Plum creeks.

Turtle Creek Valley. This great industrial valley extends within the county limits from Murrysville to its union with the Monongahela at Port Perry. Along it lie the boroughs of North Trafford, Pitcairn, Wilmerding, Turtle Creek, East Pittsburgh, and others. From Murrysville to North Trafford the valley lies near the crest of the Murrysville anticline and strata from the Brush Creek limestone up to the Morgantown sandstone are exposed. The lowest strata are exposed on the hill just west of Murrysville on the highway. These beds range from the Pine Creek limestone down to 25 feet below the Brush Creek limestone horizon. Much of the interval is made up of thin gray shales, somewhat "short" but otherwise suited for brick manufacture. Below the Brush Creek limestone the section is as follows:

Section west of Murrysville

	Feet	Inches
Brush Creek limestone		6
Brush Creek coal		8
Gray clay	5	
Sandy shale	5	
Gray clay	4	
Sandy shale	8	

Sample No. 234 represents the lower clay. This has good plasticity and high green strength. It burns to a salmon or light brown color with a firing range from 950 to 1100° C. It seems suited to the manufacture of face brick, hollow tile, conduits, sewer pipe, and paving brick. This clay or mixtures of it and the overlying 10 feet of clay and shale might well be utilized in the vicinity of Murrysville.

Down the valley, at Blackburn, is the brick yard of the Wynn Brick Company. The quarry is on the west side of the Turtle Creek valley and in it are exposed strata from the Morgantown sandstone down to the Pine Creek limestone.

Section in Wynn quarry, Blackburn

	Feet
Morgantown sandstone	10
Iron-stained shale	10
Red and buff clays (Schenley red beds)	20
Shales and sandstones	70
Ames limestone	21½
Dark shale	3
Red clay	17
Sandstone and shale	128
Pine Creek limestone	1

In former times the 17-foot clay bed below the Ames limestone was used but at present the upper bench of red clay, the Schenley red beds, is the material being used. This material (sample 104) shows good plasticity, high green strength, fires to a uniform red color and has a firing range of 1000 to 1500° C. It fuses at cone 13 or 2462° F. Analysis shows it to contain 15.94 per cent Fe_2O_3 . It appears to be an excellent material for face and common brick and for drain tile.

The clay is dug with an electric shovel and carried down to the plant by means of a bucket conveyor. It is passed through a dry pan and a Freese auger machine and burned in a series of 10 round gas-fired kilns. Face brick is the chief product. Shipment is made by way of the Pennsylvania Railroad. Sample 105 was taken from the shale bed just above the Pine Creek limestone in the above section. This is a gray slaty shale not used for making brick. It has a fair plasticity but very low green strength. It fires to light to dark red with a firing range of 100 to 1150° C. and fuses at cone 11. It is of lesser value than the clays above but could be used for common brick or in mixture with the more plastic clays above.

Below Blackburn the valley turns westward, leaving the anticlinal area, and the lower beds dip beneath the surface. This brings the Ames limestone down as the basal bed while the surrounding hills rise to or above the Pittsburgh coal. This makes available the red beds below the Ames and those below the Morgantown sandstone. They are prominently displayed between Pitcairn and the mouth of Turtle Creek.

At Pitcairn the Van Ormer Brick Company operates a plant on the main street, Broadway. The quarry is in the hill to the north behind the plant.

Section in Van Ormer quarry, Pitcairn

	Feet
Morgantown sandstone	10
Red shale) Wellersburg or	10
Shale and sandstone) Schenley horizon	10
Red clay, green at base	15
Thin sandy shale. Birmingham	40
Dark shale and coal. Duquesne	1
Clay	8
Sandstone. Grafton	3
Shale	15
Ames limestone, in benches	3
Gray shale	4
Olive-colored clay	23

The beds now being used for making brick are the shales and clays of the Wellersburg horizon, the same beds used at Blackburn (see Fig. 5). These (sample 107) have very good plasticity and high green strength. They fire to light to dark red, have a firing range of 1000 to 1150° C, and fuse at cone 11 or 2417° F. The iron content is 15.85 per cent Fe_2O_3 , practically the same as that of the Blackburn clay. The clay is suitable for face brick, common brick, and for drain tile. The main product now is face brick.

The olive-colored clay beneath the Ames limestone has the appearance of fire clay but tests made on it (sample 106) prove that it is of little value. It has good plasticity and a low green strength. It

fires to a buff color but fuses suddenly at about cone 5, probably on account of a high lime content. The Van Ormer plant is well equipped with steam shovel, jaw crusher, dry-pans, Chambers brick machine, gas-heated drying tunnels, and four coal-fired rectangular kilns. The gas for the drying tunnels is obtained from a well on the premises. The product is a series of well-colored, smooth and rough face brick.

Thence down through Turtle Creek valley the same series of red beds appears and the boroughs of Wilmerding, Turtle Creek, East Pittsburgh, and Port Perry are well supplied with brick-making materials.

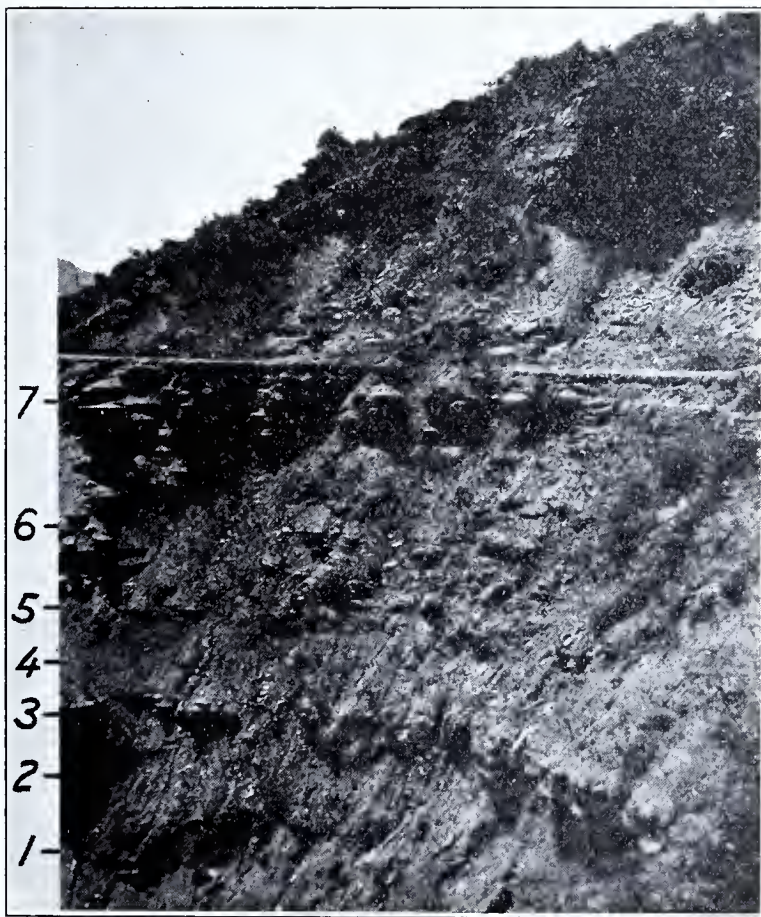


Fig. 5. Quarry of Van Ormer Brick Company at Pitcairn.

1. Ames limestone. 2. Red shale. 3. Grafton sandstone. 4. Clay. 5. Duquesne coal. 6. Birmingham shale. 7. Sandstone bed in Birmingham shale.

YOUGHIOGHENY RIVER VALLEY

Youghiogheny River borders Allegheny County on the east from one mile above Smithdale down to South Versailles. Thence the river turns in a northwesterly direction and crosses the county to enter Monongahela River in South McKeesport. It flows in a deep valley 400 feet below the surrounding hills. The Pittsburgh & Lake Erie Railroad follows its west bank and the Baltimore & Ohio Railroad the east bank.

Beginning one mile south of Smithdale, the Pittsburgh coal bed

is exposed 20 or 30 feet above rail level and fresh-water limestones appear below it. Shales in this vicinity would have to be obtained above the coal or in the interval between the Pittsburgh and Redstone coals. Thence down the river as far as Scott Haven the Pittsburgh coal remains a few feet above the railroad and the underlying beds are chiefly the Pittsburgh limestones. Occasionally in association with the limestones a bed of gray clay is to be seen. This is well displayed at Douglass a few feet above the railroad. A test of this clay (No. 283) shows it to have good plasticity and low green strength. It burns to a red color and does not fuse as readily as many of the Conemaugh clays. It probably could be used in face brick manufacture. This bed of clay is 12 feet thick and underlies 4 feet of fresh-water limestone.

North from Buena Vista the Pittsburgh limestones are underlain by blue shale which might be of value as a brick material. Down the river from this point the strata rise under the influence of the Murrys ville antiline, whose crest lies near Versailles. This brings the Morgantown sandstone up before Greenock is reached and exposes the Birmingham shales in Greenock. These shales were formerly quarried by John Butler and manufactured into common brick but the plant is now abandoned. The shale was a 10-foot bed of dark slaty shale with a thin coal at its base.

Between Greenock and Boston C. M. Harper is operating a brick plant, utilizing a hard blue shale of the Saltsburg horizon. The shale is quarried on the south side of the main road and hauled by truck to the plant on the north side of the road. The shale burns to a good red color and makes a satisfactory brick. Formerly a quarry was in operation nearer to Boston and working on the shales and clays of the Birmingham horizon and on the clays between this bed and the Ames limestone. In Boston the most promising beds are the red beds above and below the Ames limestone, which outcrops just above the town. These beds are thick and are no doubt of the same character as they are elsewhere, which would mean that they could be made into satisfactory brick. For this purpose the beds immediately over the Ames limestone and those under the Morgantown sandstone 100 feet above are most suitable.

Below Boston, in Versailles, and on the opposite side of the river the strata between the Pine Creek and Ames limestones are well exposed under the influence of the Murrys ville antiline which crosses the river at this point. This series of beds is very well exposed in the quarry of the Union Sewer Pipe Company who operate a sewer pipe plant in Dead Mans Hollow one mile below Boston and opposite Versailles. This quarry shows a complete section from the Ames limestone down to the Buffalo sandstone.

Section in quarry in Dead Mans Hollow

	Feet	Inches
Ames limestone	1	
Clay	18	
Shale	16	
Clay	5	
Shale	12	
Blue-gray shale	3	
Gray and yellow shale	32	

Woods Run limestone	3	
Woods Run coal	3	
Clay	6	
Shale	1	
Clay	3	
Limestone		2½
Shale	36	
Pine Creek limestone	1	
Buffalo sandstone	25	

Various members of the section have been used but at present the material used for sewer pipe manufacture is the shale just above the Pine Creek limestone. The quarry shows an unusually good series of shales and clays and good brick or tile could be made from several members. The shales above the Woods Run limestone look particularly good. The sewer pipe are burned in round coal-fired kilns and are shipped by way of the Pittsburgh & Lake Erie Railroad.

Down the river from this point the axis of the anticline is passed and the strata dip northwest so that the Ames limestone and its clays are again at rail level 1½ miles below Dead Mans Hollow. Thence to the mouth of the river the upper Conemaugh strata appear and are mainly sandy shales and sandstones of little value.

Unconsolidated sands, gravels and clays occur along the river both on alluvial plains and on elevated terraces 150 to 200 feet above the river. These latter are covered with the deposits of the Carmichaels formation. Although these are chiefly sandy or gravelly there are beds and pockets of yellow or white clay among them. This clay has been described under Greene and Washington counties and doubtless similar clay is to be found on the Youghiogheny. None of these surface clays are now being worked.

Another future source of clay may be the fire clays which underlie the Upper Freeport and the Lower Kittanning coal beds in the region between Greenock and McKeesport. These coals are brought nearer the surface than usual by the Murrys ville anticline. One mine, the Hubbard, is now mining the Upper Freeport coal at Versailles, (see No. 331A., B., C.) and many test holes have been sunk to determine the character of the coals of the Allegheny group. The Upper Freeport coal apparently is underlain by a clay varying from one to 4 feet thick, and the Lower Kittanning coal is underlain by clay which at Greenock seems to be 19 feet thick. As yet we know little about the quality of these, but if they are as good as they are elsewhere we would at least expect the material to be buff-burning semi-fire clay. If so, it could be used in the manufacture of buff face brick, sewer pipe, paving brick, and fireproofing. There is also the possibility that good fire clays may be found, in which case fire brick could be made. The use of these clays awaits the development of the coals, which are rather deep for present mining. The clay of the Hubbard mine fuses at cone 20 and is moderately plastic. It is suitable for low heat duty refractories and face brick.

Between Youghiogheny and Monongahela rivers. In the high divide area of Lincoln, Elizabeth, and Forward townships, the rocks range from the Pittsburgh coal up through the Monongahela group and on the hilltops in the southern part, into the Washington group. About 70 feet above the Pittsburgh coal is the Redstone coal which in this

area is of workable thickness. It is underlain by a crumbly, somewhat limy clay 5 to 10 feet thick. This probably never is true fire clay but could perhaps be used in making brick. Another persistent clay horizon lies beneath the Benwood limestone and above the Sewickley coal. This also is a pseudo-fire clay of no great value. Shales above the Pittsburgh coal in this district are generally sandy or are too intimately associated with fresh-water limestones to be of much importance in brick-making. This area is not readily accessible and probably will never have much importance in the manufacture of clay products.

MONONGAHELA RIVER VALLEY

Monongahela River enters the county in its extreme southern corner and flows in a winding course northward and westward to its junction with Allegheny River at Pittsburgh, a distance of about 36 miles. At Milesville where the river enters the county its surface is about 733 feet; and at its mouth it is 703 feet above sea level. It flows in a deep valley with the hills rising abruptly on both sides to heights of 350 to 450 feet. Terraces 900 to 980 feet above sea level or 200 to 250 feet above the present river are covered with the Carmichaels formation. A second series of terraces 20 to 50 feet above the river represent the more modern alluvial plains.

The river is bordered by the Pittsburgh & Lake Erie, the Pennsylvania, and the Baltimore & Ohio railroads. The channel has also been improved by a series of locks so that navigation is provided as far as Morgantown, West Virginia. The outcrop of the Pittsburgh coal at a convenient distance above the river has given to the valley an industrial character of great importance.

The strata exposed in the valley walls are those of the upper half of the Conemaugh group and the entire Monongahela group. The Pittsburgh coal outcrops 30 feet above the river near Elkhorn and 180 feet above near Lock No. 3. Along this part of the river, therefore, the upper part of the Conemaugh group is exposed where not obscured by terrace gravels. These Conemaugh strata include the Pittsburgh limestones and it is unlikely that much good brick material is present. The Pittsburgh coal in this area generally has a 1-foot parting of clay or shale between the main bed and the roof coal. (Fig. 6.) The parting, called draw slate, is usually semi-refractory and might be saved during coal mining operations and used in the manufacture of low heat duty refractories. Above the Pittsburgh coal are excellent exposures of thin dark shale with some sandstone layers. This shale seems to be the most available material for brick-making in the region. Sample 218 is from this shale as exposed one mile north of the Monongahela City bridge. From Milesville to Lock No. 3 this shale is generally at a convenient height for quarrying and could easily be utilized. Tests show that this shale has good plasticity and good green strength. It fires to a red or brown color but seems to be of little value on account of its poor firing qualities.

From Lock No. 3 to the Elizabeth bridge the Pittsburgh coal rises from 180 feet to 225 feet above the river and this makes the upper Conemaugh strata available. Sandy shales and sandstones seem to predominate and no clays or shales of value were noted. From

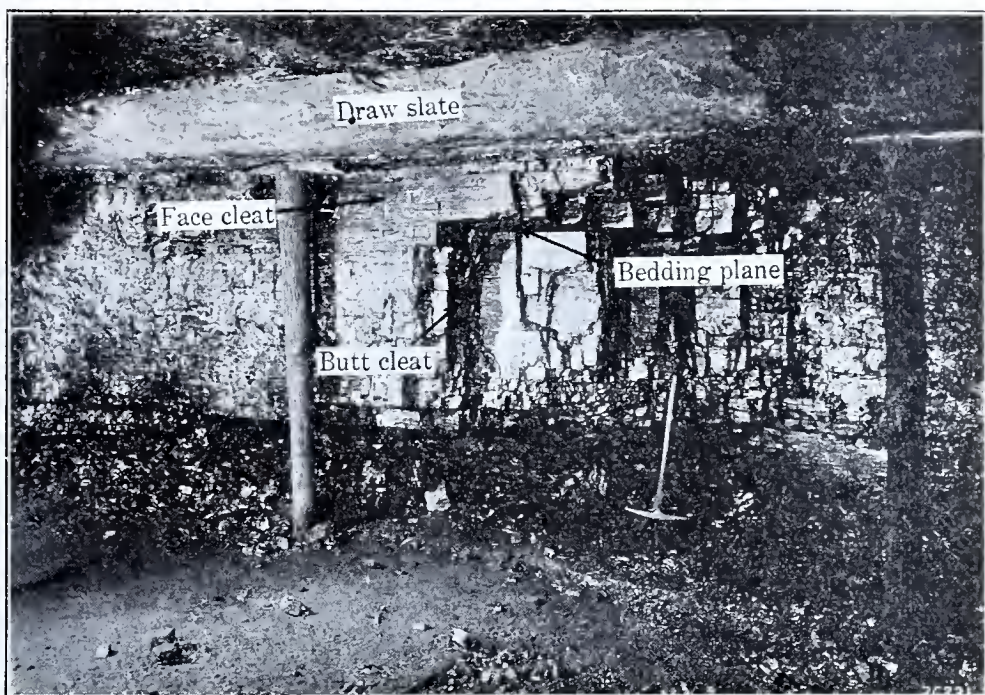


Fig. 6. Pittsburgh coal bed and draw slate.

Elizabeth to McKeesport the Pittsburgh coal bed is 200 to 235 feet above the river and the exposed rocks are of Conemaugh age. In Clairton, red beds of the Ames horizon are well exposed and sample 217 is from such material taken from an outcrop near the Clairton National Bank. It represents an average of a 20-foot bank of red clay and shale grading into buff at the top. Much of this material should be available in and around Clairton. The tests indicate that it has good plasticity and high green strength but it overfires and swells at 1000°C . This poor firing quality militates against its use in brick-making.

Section across the river from Clairton

	Feet
Morgantown sandstone	15
Red and green shales	20
Red clay (Wellersburg)	20
Birmingham shale	20
Buff clay	3
Buff clay shale	15

Sample 219 represents the red and green shale just under the Morgantown sandstone. As in Clairton, this shale shows good plasticity and high green strength but exhibits poor firing qualities and is of little value. Having good plasticity and green strength, it could no doubt be mixed with other shales and a satisfactory product made. It is apparent that in the Clairton region there is ample material for brick manufacture, if the proper mixtures could be made.

In and near McKeesport the exposed rocks are of upper Conemaugh age, with the Morgantown sandstone forming heavy layers near rail level. No particularly good clays or shales were noted. Down the river through Duquesne, Braddock, Homestead, Hays, and to the "Point" in Pittsburgh the Pittsburgh coal is high above the river, and near rail level the Ames limestone and its accompanying clays, the Birmingham

shale (Fig.7), and the Wellersburg clays are well exposed. There is thus abundant material of fine quality for the manufacture of face brick, drain tile, and fireproofing. Brick yards using these materials are located at Braddock, Homestead, and on the South Side in Pittsburgh.

The J. B. Coen Brick and Tile Works is located in Homestead along



Fig. 7. Birmingham shale at Mt. Washington Tunnel, Pittsburgh.

West Run on Forest Avenue. Their quarry (see Fig. 8) is on the east side of West Run, back of the plant. The following section is exposed:

Section in Coen quarry on West Run, Homestead

	Feet
Morgantown sandstone	10
Red clay	5
Greenish clay, Wellersburg	5
Red clay	5
Thin blue shale, Birmingham	25
Jointed shale, black at base, Birmingham	11
Thin coal, Duquesne	..
Blue clay with limy stringers	5
Olive shaly sandstone, Grafton	5
Blue clay shale	5
Red laminated shale	5
Blue clay shale	5
Ames limestone	2

For brick making, the whole section down to the Ames limestone is used, sorting out the harder sandstone blocks. Sample 197 is the ground mixture. This has good plasticity and fair green strength. It fires to light or dark red, and has a firing range of 1000 to 1150°C. It fuses at cone 7. From it the company makes an excellent line of dark red common brick. These are burned in six up-draft scove kilns. The clay is crushed in dry pans and molded in a Freese auger machine.

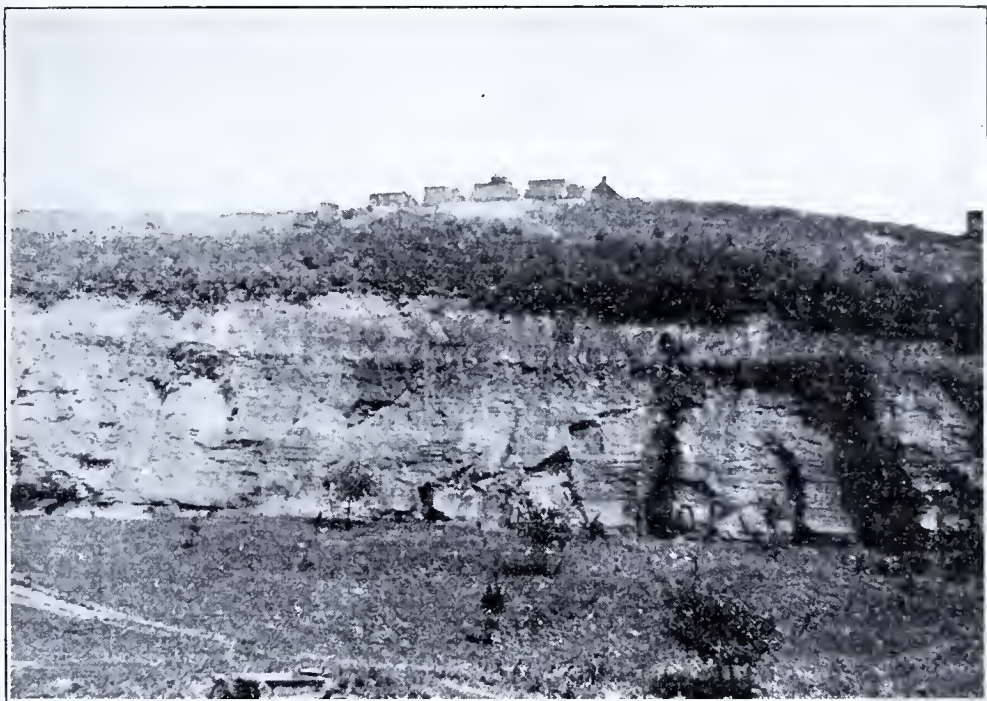


Fig. 8. Quarry of J. B. Coen Brick and Tile Works, West Homestead.



Fig. 9. Wellersburg clay at Bigelow Boulevard, Pittsburgh.

Sample 198 is from the 5-foot blue clay layer just below the thin streak of Duquesne coal. Although a good looking clay the tests show it to be of no value on account of a short or practically no firing range. A high content of lime is probably the cause of its peculiar burning qualities.

The plant of M. Lanz and Sons is located at 34th and Jane Streets on the south side of Monongahela River in Pittsburgh. They have quarried out a steep section of the hillside exposing the following rocks:

Section in Lanz quarry, South Side, Pittsburgh

	Feet
Pittsburgh limestone	1½
Clay	2
Connellsville sandstone	9
Clay	19
Sandstone	2
Shaly sandstone	7
Clay and nodular limestone	2
Sandy shale	5
Clay with iron ore nodules	34
Shale and sandy shale	5½
Morgantown sandstone	25
Red and mottled clays, Wellersburg	25
Thin dark shales, Birmingham	45

At present the material used for brick manufacture is obtained from the strata above the Morgantown sandstone, eliminating the sandstone and limestone layers. (Fig. 9). Sample 150 is from the Birmingham shale beds at the base of the section. This material shows fair plasticity but very low green strength. It fires to salmon to dark red color with a firing range of 1000 to 1200°C. and fuses at cone 9 or 2345°F. It is not now used but has been made into face brick and tile. It is not considered as good as the upper shales and clays. The shales used are ground in dry pans, passed through a Freese auger machine, and burned in round or square coal-fired kilns. The chief product is red face brick.

Almost directly across the river and high on the bank is the plant of the Squirrel Hill Brick Company at Bigelow and Bristol streets. Their materials consist of 4½ feet of purplish clay and 10 feet of greenish shale 80 feet below the Pittsburgh coal and above the Connellsville sandstone. Fresh-water limestone is present in the section but by careful selection a workable mixture may be obtained. The plant makes a good grade of red face brick and common brick. Shipment is entirely by truck.

The next brick plant down the river is that of Sankey Brothers at 18th Street, South Side (see Fig. 10). The quarry is in the hill east of the plant and exhibits the following section:

Section in Sankey Bros. quarry, South Side, Pittsburgh

	Feet
Yellow shale	16
Red and purple shale	4
Sandstone, Connellsville	15
Black shale	2
Limestone)	1
Dark sandy shale) Clarksburg	4
Limy clay, buff to red)	15
Shale and sandstone, Morgantown	20

For making brick the upper 20 feet, that is, the shale and clay above the Connellsville sandstone is the chief material used. With it is usually mixed some of the red clay below the Clarksburg limestone. Sample 148 represents the upper shale. This has good plasticity and fair green strength. It fires to salmon to dark red color with a burning range of 1000 to 1200°C. and fuses at cone 12. Sample 149 was taken from the clay bed under the Clarksburg limestone. It shows a close resemblance to No. 148 in the tests but fuses at a much lower temperature, cone 5. It could be used alone or could be mixed with the upper



Fig. 10. Sankey Bros. brick yard, South Side, Pittsburgh.

shales. Sankey Brothers operate a well equipped plant and make red face brick, tile, and common brick.

REGION WEST OF MONONGAHELA AND OHIO RIVERS

The southern townships, Baldwin, Mifflin, Snowden and Jefferson, back from Monongahela valley, form a high plateau of Monongahela strata, penetrated by the long valleys of Peters Creek, and Lick, Lewis, Thompson, and Streets runs. These valleys give access to the region by rail. Along these valleys upper Conemaugh strata are exposed, with the Pittsburgh coal outcropping high above the stream. This coal is mined extensively along these valleys. No clays or shales are being used along these valleys but it seems probable that the Wellersburg or Schenley red beds could be worked in the lower part of many of the streams. Farther up the valleys the shales and clays of the Connellsville horizon might be utilized. The shales above the Pittsburgh coal might also be used but frequently in this region these are too micaceous to be of any value. The highlands between the streams in this southern area are underlain with upper Monongahela strata including many limestones, and it is not likely that sources of clay will be sought there under those conditions.

West of these townships the Monongahela strata are prominent in similar plateaus. In Bethel and Upper St. Clair townships much of the overlying Washington group is also exposed. Outcrops are not conspicuous, much of the territory is given over to residential purposes, and little shale development is to be expected.

Sawmill Run cuts into the highland from the West End district of Pittsburgh and exposes the upper half of the Conemaugh group. The brick plant of the James T. Fox Company is located along this run in the West End at Shaler and McKnight streets. The section exposed in the quarry is as below:

Section in Fox quarry, West End, Pittsburgh

	Feet
Buff shale	10
Nodular sandy limestone	2
Red clay	8
Heavy sandstone	15
Soft clay with limy nodules	6
Gray laminated shale	8
Heavy sandstone	8
Black coaly shale	1½
Gray clay	3
Dark iron-bearing limestone	1½
Blue clay with limy lumps	10

The company formerly used the buff shale and red clay of the upper part of the section but now are using chiefly the 8-foot layer of gray laminated shale, making from it a good grade of red brick. The lowest member is a blue clay with limy lumps in it. This material (No. 140) shows poor plasticity and low green strength. It fires to light to dark red with a burning range of 1000 to 1250°C. and fuses at cone 14. It seems to be of little value but if a greater amount of the lime could be removed it might be used with the other material. The plant is equipped with a jaw crusher, two dry pans, a Freese auger machine, and four scove kilns. Shipment is by truck.

The longest valley in the region is that of Chartiers Creek. This heads in Washington County and traverses the southwestern part of Allegheny County from south of Marshalsea to McKees Rocks. It takes a winding course in an older, widely terraced valley. It is followed by the Pittsburgh, Chicago, Cincinnati & St. Louis Railroad and the Wabash Railroad. The latter leaves Chartiers Creek at Bridgeville and passes west of Millers Run. One branch of the P. C. C. & St. L. follows up Robinson Run westward from Carnegie. From the mouth up as far as Crafton, Chartiers Creek cuts well below the Ames limestone and there are excellent opportunities for developing the clays and shales which lie between the Saltsburg and Morgantown sandstones. The various red beds are well displayed along the banks of the creek and are in excellent position for quarrying. As known from their use elsewhere these beds are suitable for face brick, common brick, and drain tile.

From Crafton to Carnegie the railroads and the valley cut chiefly into the upper hundred feet of the Conemaugh group, less valuable for brick making than the lower portion. Thence up the valley through Bridgeville and Marshalsea to the Washington County line, the exposures are of the strata near the Pittsburgh coal, especially the overlying shales.

At Bower Hill Station, near Bridgeville, is the brick plant of the

F. C. Mayer Manufacturing Company which makes chiefly paving brick, with a smaller amount of face brick. The Pittsburgh coal is mined at the level of the kilns. Above it there lies 10 feet of dark shale not used, and on this 20 feet of shale varying from dark at the base through bluish to yellow and micaceous at the top. Overlying the shale are sandy or gravelly clays of the Carmichaels formation which are stripped off before the shale is quarried. Paving brick is made from the 20-foot shale mentioned above. Sample 115 represents the ground mixture. This shows fairly good plasticity and low green strength. It burns to light or dark with a burning range of 1000 to 1150°C. and fuses at cone 12 or 2435°F. The tests show that it can be used for fireproofing as well as paving brick. The shale is dug with a Thew electric shovel, and trammed by mule to the tipple. It is ground in dry pans, passed through a Freese auger machine, and the brick burned in rectangular down-draft kilns, fired with coal.

The use of these shales above the Pittsburgh coal is of interest because so much of that horizon is easily available, made so by the railroads parallel to the coal outcrop. Often, however, the shale at this horizon becomes more micaceous and its plasticity is decreased to such an extent that it is worthless.

On Robinson Run between Carnegie and McDonald, the lower strata are of upper Conemaugh age, with the Pittsburgh coal usually about 100 feet above the railroad. The Conemaugh strata are utilized by the Walkers Mills Stone and Brick Company at Walkers Mills. They manufacture light red chimney brick and a long line of face brick of many shades. Their shale bank shows 30 feet of heavy sandstone (probably the Connellsville) overlain by 10 or 12 feet of shale, which is the material now used. This shale is buff or greenish and carries large niggerheads of limy sandstone which are removed by hand. Sample 108 is the average of this shale. It has good plasticity and high green strength. It burns to light or dark red with burning range of 1000 to 1200°C. and fuses at cone 15. The shale is dug with a Thew electric shovel, trammed over a bridge to the plant where it is ground in dry pans. It is molded in a Freese machine, dried in tunnel driers, and burned in round coal-fired kilns.

Conemaugh shales of excellent quality are also well exposed from Greggs or Bishops Corners to McDonald. Sample 109 is taken from a road cliff of shale at Gregg, 2 miles east of Oakdale. Its plasticity is very good and its green strength fair. It fires to light red or brown with a firing range of 1000 to 1150°C. and fuses at cone 12. It seems suitable for making red face brick, common brick, and drain tile.

North of Robinson Run the western townships have the Monongahela group in their higher land, with the Pittsburgh coal as the important member. In the valleys the Conemaugh group is exposed down to and somewhat below the Ames limestone. Montour Run and Moon Run extend up from Ohio River into these townships and each has a railroad, built chiefly on account of the valuable Pittsburgh coal which lies near the heads of the valleys. The Ames limestone appears along Moon Run up as far as Beacon and along Montour Run almost to the Cliff mine. Below these points therefore there is opportunity for the development of the lower Conemaugh strata. Above these points the upper Conemaugh strata may be utilized, and still higher up the shales above the Pittsburgh coal are available. At present the clay and shale in this area are not used.

Table 4

Physical tests of Allegheny County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slacking minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Max. shrinkage at cone	Fusion point at cone	Best burning range cone	Firing color	Suggested uses
104	27.4	8.3	4	319	6.5	05	13	07-1	dark red	face brick, common brick, drain tile
105	19.8	1.9	4	72	11.0	1	11	07-1	lt. to dark red	common brick
106	22.1	4.4	6	208	7.5	1	5	Poor	buff	no value
107	25.8	8.5	5	424	6.5	1	11	07-1	lt. to dark red	face and common brick, drain tile
108	28.4	8.0	7	326	8.9	4	15	07-4	lt. to dark red	face and common brick, drain tile
109	24.3	3.3	5	270	10.0	1	12	07-1	lt. red to brown	face and common brick, drain tile
115	18.7	2.9	4	207	7.1	1	12	07-1	lt. to dark red	face and paving brick, fire proofing
127	22.7	6.3	-----	-----	8.7	4	16	07-4	lt. buff to gray	little value
128	24.7	6.0	-----	-----	10.2	4	7	07-1	salmon to tan	buff face brick color poor
129	23.7	2.8	4	86	11.5	02	13	07-4	lt. red to brown	red face brick
130	25.1	4.2	4	121	10.3	4	12	07-4	lt. red to red brown	little value
131	19.4	3.5	5	74	8.3	1	13	07-4	lt. red to brown	little value
132	24.6	4.8	5	221	7.9	1	7	07-1	lt. to dark red	face brick, drain tile
133	23.3	4.5	5	146	10.1	4	12	07-4	buff to brown	face brick
134	23.6	4.9	5	177	9.4	6	15	07-6	buff to brown	face brick
135	21.9	5.4	5	126	3.9	1	11	07-1	med. red to dark red	face brick, common brick, drain tile
136	26.3	6.8	4	220	11.3	4	13	07-4	lt. to dark red	face brick
137	21.1	5.6	6	269	8.8	4	15	07-4	salmon to dark brown	face brick, drain tile, fire proofing
138	26.3	9.6	9	443	7.1	1	12	07-1	lt. to dark red	face brick, drain tile, fire proofing
139	22.3	7.1	8	282	7.9	4	13	07-4	lt. to dark red	face brick
140	23.8	6.3	5	133	7.2	4	14	07-6	lt. to dark red	little value
145	19.2	7.0	6	-----	3.6	02	7	05-1	lt. to dark red	face brick, common brick, drain tile
146	23.5	4.1	13	-----	6.5	4	8	07-4	lt. to dark red	face and common brick, drain tile
147	19.3	1.6	8	-----	8.3	4	5	07-4	lt. to dark red	face and common brick, drain tile
148	21.4	5.6	6	-----	7.0	4	12	07-4	salmon to dark red	face and common brick, drain tile
149	21.3	7.2	8	-----	3.2	02	5	07-4	lt. to dark red	face and common brick, drain tile

Physical tests of Allegheny County clays—Continued

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slacking minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Max. shrinkage at cone	Fusion point at cone	Best burning range cone	Firing color	Suggested uses
150	18.6	1.6	7	-----	9.7	4	9	07-4	salmon to dark red	face and common brick, drain tile
151	18.4	7.2	9	-----	7.2	4	8	07-4	lt. red to dark brown	face and common brick, drain tile
152	17.4	3.2	12	-----	7.4	4	6	07-4	pink to dark red	face and common brick, drain tile
153	17.7	5.4	6	-----	2.0	02	8	07-4	buff to dark red	no value
154	21.2	6.0	7	-----	6.7	11	27	02-9	cream to gray	face brick, sewer pipe, fire proofing
155	22.8	4.5	5	-----	7.8	4	7	05-4	red to dark red	face brick fire proofing
156	23.2	6.6	6	-----	8.8	1	9	07-4	red to dark red	face brick, sewer pipe, fire proofing
157	23.9	4.3	6	-----	6.9	1	13	05-4	red to dk. brown	face brick, paving brick, sewer pipe
158	22.1	6.7	7	-----	5.0	11	20	02-9	dark buff	little value
197	19.6	4.3	6	270	4.8	02	7	07-05	lt. to dark red	face brick
198	20.8	5.6	5	77	5.2	1	9	none		no value
217	25.8	5.4	4.5	342	7.5	05	10	-07	red to brown	no value
218	25.8	4.5	5	225	9.1	02	13½	Poor	red to brown	no value
219	21.7	5.6	4	284	5.5	05	12	Poor	red to brown	no value
234	43.2	9.2	9	342	6.3	02	16	010-02	salmon to lt. brown	face brick, sewer pipe, paving brick
235	23.7	4.6	5	252	7.7	05	12½	010-07	red to brown	face brick
283	4.6	4.6	6	100	4.1	05	10	-----	lt. red to dark red	face brick?
331A	16.3	4.0	-----	261	3.6	4	20	05-4	lt. buff to gray	face brick
331B	19.9	5.3	-----	270	7.6	4	20	05-4	lt. buff to gray	face brick
331C	20.6	4.8	14	207	5.9	4	20	05-4	lt. buff to gray	face brick

Table 5

Chemical analyses of Allegheny County clays

NO	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
104	6.50	53.39	15.94	.18	13.89	1.57						.17
107	7.27	58.13	15.85	.04	14.11					.01		
108		53.11								.06	.04	.79
109	5.22	57.75	6.30	1.21	24.35	.52	1.12					
146	5.32	56.83										
148	5.68	62.60	5.43	.53	17.91	1.90	2.91					
149	15.23	44.68	4.11	.62	26.52	6.07	1.04			.10		.38
150	12.31	55.56	9.25	.78	14.52	.71	1.78			.20		
152	7.36	52.41	6.32	.47	25.76	.69	.30			.22	.56	.1377
158	9.39	52.95	8.72	.77	24.12	1.61	1.64			.09	.21	.40
217	6.36	55.65										
218	8.05	52.33	13.01	.86	19.75	.98	1.98	1.82	.26	.43	.51	.45
219	6.47	55.90				1.14	3.05					.66
234	6.18	60.22	11.38	1.21	18.18	Tr.	.58					
235	8.11	53.37										
331A	9.16	64.50	3.72	1.09	21.64	.58	1.08	2.55		.02		.88
331P	8.33	58.55	3.52	.97	26.32	.61	.94	1.66				
331C	8.56	58.37	3.71	1.33	22.54	.44	.82	2.22	1.25	.03	.03	.76

Localities from which samples were obtained.

104. Red clay and shale, Wynn Brick Company, Blackburn.
105. Lower shale, Wynn Brick Company, Blackburn, not used.
106. Clay below Ames limestone, Van Ormer Brick Company, Pitcairn, not used.
107. Red clay and shale, Van Ormer Brick Company, Pitcairn.
108. Shale, Walkers Mills Stone and Brick Company, Walkers Mills.
109. Olive shale along road 2 miles east of Oakdale.
115. Shale, F. C. Mayer brick plant, Bridgeville.
127. Underlay along road at Fair Oaks.
128. Clay on river road opposite Sewickley.
129. Shale above Pine Creek limestone, Wittmer.
130. Shale below Pine Creek limestone, Wittmer.
131. Shale above Pine Creek limestone near mouth of Powers Run.
132. Shale above Pine Creek limestone, Harmarville.
133. Shale above Pittsburgh coal, Milliken Brick Company, Wilkinsburg.
134. Bin sample, Milliken Brick Company, Wilkinsburg.
135. Clay from pit of John Ward and Sons, East End, Pittsburgh.
136. Upper shales, Hooper Brothers quarry, East End, Pittsburgh.
137. Lower purple clay, Hooper Brothers quarry, East End, Pittsburgh.
138. Bin sample, Gough Brick and Tile Company, Nelson Street, Pittsburgh.
139. Upper shale, Gough Brick and Tile Company, Nelson Street, Pittsburgh.
140. Lower unused clay, Jas. T. Fox Company yard, Shaler St., West End, Pittsburgh.
145. Red bed, Iron City Brick and Stone Company, Stanton Ave., Pittsburgh.
146. Buff shale, Entress Brick Company, Bedford Avenue, Pittsburgh.
147. Bin sample, Booth & Flinn brick yard, Soho district, Pittsburgh.
148. Upper shales, Sankey Brothers brick yard, South Side, Pittsburgh.
149. Lower shales, Sankey Brothers, South Side, Pittsburgh.

150. Lower shale (unused), M. Lanz Brick and Tile Company, 34th St., Pittsburgh.
151. Bin sample, Martin Brick and Paving Company, Hites Station.
152. Dark shale, McFetridge Brothers Brick Company, Creighton.
153. Nodular clay along road, Natrona Heights.
154. Underclay in railroad cut, Allison Park Station.
155. Clay, Gourdhead Run road, near Allison Park.
156. Clay along road just west of Talleycavey.
157. Clay along road under high bridge, Emsworth.
158. Flint-like clay along river road opposite Ambridge (Allegheny-Beaver Co.)
197. Bin sample. J. B. Coen Brick and Tile Company, West Homestead.
198. Clay below Birmingham shale, J. B. Coen quarry, West Homestead.
217. Red clay along streets in Clairton.
218. Shale along river road 1 mile north of Monongahela City on east side of the river.
219. Shale, east side of river opposite Clairton.
234. Clay below Brush Creek coal on road just west of Murrys ville.
235. Shale over Woods Run limestone on road just west of Abers Creek bridge, west of Murrys ville.
283. Clay along railroad at Douglass Station (Suterville).
- 331 A, B, C. Upper Freeport clay, Hubbard mine, Versailles.

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ARMSTRONG COUNTY.

This county lies east of Butler County and west of Indiana County, and is bounded on the north by Allegheny River and Red Bank Creek which separate it from Clarion County. On the south it is separated from Westmoreland County by the Kiskiminetas River. Its county seat and largest city is Kittanning, which lies in about the center of the county on the Allegheny River.

The topography of the county is that of an upland plateau of rolling character with a general elevation of 1300 to 1600 feet above sea level. This is very much broken or dissected by many deep, winding valleys whose bottoms lie from 100 to 500 or 600 feet below the plateau. The larger streams have cut channels below the pre-glacial valley bottoms and these latter remain as elevated terraces high above the streams and covered with gravels. The upper courses of some of the longer tributaries are flowing in broad low valleys which are probably their old pre-glacial courses. No part of the county was within the borders of the ice sheet and the only glacial materials seen are the gravels brought down Allegheny River by the present and former streams.

The drainage of the county is all into Allegheny River. This enters the county at its most northerly point, above Parkers Landing, flows along the boundary between Armstrong and Clarion counties to the mouth of Red Bank Creek, then flows directly through the county past Kittanning, leaving it at Freeport. The tributaries entering the river from the west are curiously short as compared with those from the east. Only Buffalo Creek is of any length. The streams which enter the river from the east are much longer, rising far east of the county line and flowing in tortuous courses across the eastern part of the county. From north to south the important streams are as follows: Red Bank Creek rises in Jefferson County and flows past New Bethlehem to unite with Allegheny River at Red Bank; Mahoning Creek rises in Jefferson and Clearfield counties and flows west to join the Allegheny at Mahoning; Cowanshannock Creek joins the Allegheny north of Kittanning; Crooked Creek rises in Indiana County and after a very winding course reaches the Allegheny at Rosstown; and finally, on the south border, is Kiskiminetas River.

The county is well served by railroads, these usually taking advantage of the stream valleys for easy grades. The Pennsylvania Railroad has divisions following the east bank of Allegheny River, the north bank of Red Bank Creek, and the south bank of Kiskiminetas River. The Pittsburgh, Shawmut, and Northern Railroad follows the west bank of the Allegheny River from Freeport, crosses the river and follows up Mahoning Creek. The Buffalo, Rochester & Pittsburgh Railroad comes into the county from the west near Nichola, and crosses the county, using Pine Creek Valley from Mosgrove eastward. Other roads which touch the county and serve smaller areas are the Buffalo & Susquhanna, the Baltimore & Ohio, and the Bessemer & Lake Erie. Transportation by water from Pittsburgh to Kittanning is possible and plans are under consideration for further improvement of the Allegheny by means of locks above Kittanning. Plans are also proposed for the improvement of Kiskiminetas River which in the early days was navigable as a part of the great Philadelphia-Pittsburgh canal system.

STRATIGRAPHY AND STRUCTURE.

The rocks of the county are all of sedimentary origin. Their original horizontal position has been somewhat disturbed by movements during the forming of the Appalachians but no severe folding is present in the county. The strata make a series of very gentle folds whose long directions or axes trend N. 35° E. or thereabouts. Dips which in western Pennsylvania are normally not over 25 feet per mile, in these folds often become as great as 200 to 300 feet per mile. This of course is visible tilting and affects the altitude of the clay and coal beds to an important degree. The minor folds are of little interest to the clay worker but it might be well to call attention to some of the more pronounced ones. Beginning in the southeast the first structure is the Elders Ridge syncline, a down-folded area in which the Pittsburgh coal and some of the overlying strata are preserved. The axis of this fold crosses Kiskiminetas River two miles above Avonmore. Northwest of this the next prominent fold is the Roaring Run anticline, an up-fold which crosses Kiskiminetas River near the mouth of Roaring Run below or northwest of Salina. This brings up nearly the entire Allegheny group in a fine fold between Salina and Apollo. After a few minor anticlines and synclines which affect the altitude of the beds but little the next important fold is the Kellersburg anticline which enters the county from the southwest near West Winfield, crosses Allegheny River one mile south of Rimer, and crosses Red Bank Creek between Leatherwood and New Bethlehem.

The strata exposed within the county include about 200 feet of the Monongahela group, the Conemaugh group of about 650 feet of strata, the Allegheny group, 350 feet, the Pottsville series with a thickness of 125 feet, and the lowest exposed, the Burgoon sandstone of the upper Mississippian period amounting to approximately 300 feet. This gives a total of about 1625 feet of exposed rocks in the county.

The Monongahela group is to be seen only in the Elders Ridge area where a syncline has preserved the Pittsburgh coal and above it 200 feet of strata including the Redstone and Sewickley coals and in the higher hills the Benwood limestone.

The Conemaugh group, which contains a great deal of good shale but very little fire clay or coal, covers most of the southern half of the county and the higher areas in the northern half.

The Allegheny group, which is the most important for its coals and fire clays, is seen along Allegheny River from Red Bank down to Freeport, along the Kiskiminetas and Crooked Creek valleys, and over most of the upland areas in the northern portion of the county.

The Pottsville series, a mass of heavy sandstones with minor intervals of shale and fire clay, lines Allegheny River above Red Bank, and makes very prominent outcrops along Mahoning and Red Bank creeks.

The Mississippian strata, termed the Burgoon sandstone, outcrop only along Allegheny River in the northern part of the county, and along the lower courses of Red Bank and Mahoning creeks. There has been in the past a great deal of confusion about these strata but it is now believed that the lowest strata of the Pottsville series in this region are the Upper Connoquenessing sandstones and that these rest unconformably upon the rocks of Pocono age, the Burgoon sandstone.

The Lower Connoquenessing and the Sharon divisions of the Pottsville are absent and the Mauch Chunk is absent from the top of the Mississippian. The Mississippian strata of the county are sandstones with minor amounts of greenish shale and are of little interest as sources of clay.

Generalized section of Armstrong County

	Feet
Monongahela group	
Benwood limestone	35
Interval	83
Sewickley coal	2
Interval	63
Redstone coal	1
Interval	35
Pittsburgh coal	7
Conemaugh group	
Interval	40
Connellsville sandstone	30
Interval	100
Morgantown sandstone	20
Interval	100
Ames limestone	2
Interval	125
Pine Creek limestone	2
Interval	60
Brush Creek limestone	1
Shale, coals, and good clays	30
Mahoning sandstone	50
Shale	20
Allegheny group	
Upper Freeport coal	3½
Clay	3
Upper Freeport limestone	6
Bolivar clay	4
Shale, clay, sandstone	43
Lower Freeport coal	3
Interval	30
Upper Kittanning coal	1
Interval	60
Middle Kittanning coal	2
Clay	1
Interval	55
Lower Kittanning coal	4
Clay	4
Dark shale	15
Clay	3
Shale and clay	10
Vanport limestone	8
Interval	27
Clarion coal	4
Clay	5
Interval	40
Brookville coal	2
Pottsville series	
Homewood sandstone	40
Mercer shales, coal, and clay	25
Upper Connoquenessing sandstone	40
Pocono series	
Sandstones and some shale	200

CLAY RESOURCES BY DISTRICTS

The clay resources of the county can best be discussed by districts and by description of conditions along the main transportation lines which are the stream valleys.

THE DISTRICT WEST OF ALLEGHENY RIVER

This includes the western uplands and their streams, such as Buffalo Creek, Limestone Run, etc. It is crossed in the north by the Baltimore & Ohio Railroad, by the Bessemer & Lake Erie Railroad west of Bradys Bend, and by the Buffalo, Rochester & Pittsburgh Railroad through Craigsville. It is also served in part by the West Winfield Railroad which connects West Winfield with Freeport. The rocks of the district are all above the Vanport limestone with the exception of an area on Buffalo Creek and its branches near Craigsville where the lower Allegheny and the upper layers of the Pottsville are exposed. By far the greater part of the upland is covered with strata of the Conemaugh group. The Kellersburg antiline is responsible for the rise of the lower rocks near Craigsville and West Winfield and due to it considerable of the Allegheny group covers the surface of the upland northeast from Craigsville to the river.

The northernmost tongue of land which belongs to the county is so narrow that its description belongs with that of Allegheny River Valley. South from Parkers Landing the district widens. Most of the upland here is in the Conemaugh group but the lower valleys expose the upper part of the Allegheny group, as at Queenstown and Fredericksburg where the Upper Freeport coal is minable. Little is known about the clay below the Upper Freeport coal nor have the clays of the lower Conemaugh group been examined. It seems unlikely that there are any good fire clays in the area but the Brush Creek clays might prove to be of good enough grade so that face brick or sewer pipe could be manufactured.

West of Bradys Bend and East Brady, Sugar Creek and its branches have thoroughly dissected the region and along these streams the greater part of the Allegheny group is exposed, with the Conemaugh group far up on the plateau. The Upper Freeport coal along Sugar Creek is said to show considerable fire clay below it and also below the Upper Freeport limestone. Usually however these clays are too full of iron nodules to be of much value. Report H5 records under the limestone 7 feet of clay with iron balls and below that 6 feet of clay without iron balls. This would be at the Bolivar horizon. Sandstones seem to overlie and underlie the Lower Kittanning coal here. The Clarion coal has a clay below it which varies from 4 to 11 feet in thickness. The Upper Kittanning Brick Co. has a plant along Sugar Run west of Bradys Bend and manufactures light buff face brick.

Section of brick plant on Sugar Creek.

	Feet
Sandy shale	1
Brown shale	6
Clarion coal	$\frac{1}{2}$
Black shale	2
Dark soft clay	2
Light blue clay	2
Harder clay	3

They mine from 6 to 11 feet of this Clarion clay and use all three grades. The clay (No. 160) shows fair plasticity and green strength. It fires to light buff to gray with a firing range of cone 3 to 8, and fuses at cone 26. It is suited to the manufacture of face brick and low heat duty fire brick.

South from the Bradys Bend region is a great expanse of upland in which the Freeport and Kittanning divisions of the Allegheny group are exposed along the Kellersburg anticline. This area is without rail facilities and is little developed. At Craigsville and on the branches of Buffalo Creek the anticline has brought up the Vanport limestone, the Clarion coal and clay, and the Pottsville sandstone. These support mining industries near Craigsville and in the West Winfield district. Just west of Worthington at Buffalo Mills on Buffalo Creek 16 feet of the Clarion clay is exposed under 2 feet of the Clarion coal. South of this the section shows:

Section south of Buffalo Mills.

	Feet
Vanport limestone	6
Shales	15
Coal with middle parting	$\frac{2}{3}$
Shale with coaly streaks	1
Clarion coal, good	2

Up Buffalo Creek and just west of Craigsville station on the Buffalo, Rochester & Pittsburgh R. R. is the plant of the Graf-Kittanning Clay Products Co. Their clay mine just above the railroad shows 24 inches of Clarion coal underlain by 10 to 20 feet of plastic fire clay. Much of it runs 16 feet and is very uniform. This clay is represented by sample 194. It is fairly plastic and has low green strength. It fires to buff to gray with a firing range of cone 1 to 8 and fuses at cone 23. It is suited to the manufacture of face brick and sewer pipe. At the base of the clay is an oolitic siderite somewhat like that seen at St. Charles. The coal is mined out later. The company also uses a shale just above the Vanport limestone. This is obtained on the hillside above the mine opening from an open pit which they may convert into a mine. This shale is just below a 3-foot bed of Lower Kittanning clay which is not now used. The firm manufactures sewer pipe and flue lining, using 1 part shale to 5 parts clay. With similar clay at West Winfield it would appear as if this Clarion clay is an important resource along Buffalo Creek and the Buffalo, Rochester & Pittsburgh Railroad and no doubt it will be still further developed.

Eastward from Craigsville the railroad follows the Pottsville sandstone for 4 miles with Allegheny strata a short distance above the tracks. Then these sandstones and the lower Allegheny beds pass below the tracks, and the rocks along the railroad are of upper Allegheny group with the Upper and Lower Freeport coals exposed just above the tracks. This condition continues through Cowansville. At this place the Hydraulic Press Brick Company has a brick plant.

Two miles east of Cowansville the railroad passes into Limestone Run Valley and down to the horizon of the Vanport limestone near Adrian. Thence to Allegheny River the Vanport limestone lies near track level and all of the Kittanning and Freeport divisions are exposed above the railroad. In this area the chief coal mined is the Lower Kittanning but no good clay seems to underlie it. The condition of the Clarion clay in this area is also unknown.

South from Buffalo Mills, Buffalo Creek carves a deep gorge in the Allegheny strata, exposing practically the whole section. At West Winfield, which lies on the Butler County line, coal, limestone, sandstone, and clay have all been mined. Both the Lower Kittanning and

the Clarion clays have been used in that area. The Duquesne Fireproofing Company formerly made tile of the Lower Kittanning clay which was 11½ feet thick. It was said to burn to a color not uniform enough for face brick. They also made sewer pipe from the Clarion clay (see Folio 115). At present the mining activity is chiefly on the Butler County side of the line and the Pennsylvania Clay Products Company is making sewer pipe from the Clarion clay (No. 196, Butler Co.). It is an excellent clay, fusing at cone 29, and could be used in the manufacture of low heat duty refractories, face brick and other things besides sewer pipe. On the Armstrong County line it lies near stream level and to the south quickly passes below the surface but it could be mined by shaft. Thence to Freeport, Buffalo Creek exposes the upper strata of the Allegheny group and on Slate Lick the Cone-maugh strata are the surface rocks.

THE ALLEGHENY VALLEY

By far the most important industrial belt through the county is the Allegheny valley. Its railroads and water transportation have given it an industrial aspect not seen elsewhere in the county and a number of industrial cities have sprung up along it. Allegheny River at the north end of the county is 860 feet above sea level and at Freeport 760 feet. The hills on either side rise to elevations of 1200 to 1400 feet above sea level or 400 to 600 feet above the river bottoms. The river is lined with a high rock terrace covered with glacial gravel; nearer the river level are other gravel terraces of later glacial age and a narrow flood plain. Dams and locks provide navigation up to Kittanning and plans are underway for the extension of the system. Beginning at the north the geology and clay resources are as follows: From Emlenton to Foxburg the river flows between walls of Pottsville and Burgoon sandstones, the lower portions of the Allegheny group appearing only on the highest knobs.

Section below Emlenton.

	Feet
Allegheny group	
Shale with iron nodules	20
Vanport limestone	10
Shale with iron nodules	12
Scrubgrass coal	2
Shale	13
Clarion coal	3½
Concealed	30
Upper Pottsville	
Homewood sandstone	55
Mercer division of Pottsville	
Shale and concealed	15
Coal (Mercer)	1
Bluish clay	..
Dark shale	25
Sandstone and shale	8
Coal blossom	..
Dark iron bearing shales	15
Connoquenessing and Pocono	
Massive sandstones	115
Concealed to river	20

There is probably little of value in the clays of this area. The shales are dark and full of iron nodules and the fire clays of the Allegheny group, if present, are high up on the sides of the valley.

The same section prevails to Parkers Landing and Bear Creek. A great part of the surface on the Armstrong County side of the river is made up of a high terrace covered with glacial gravel of Illinoian age. In Bear Creek ravine the Mereer shales are well exposed but seem to be of no great promise. Below this point for 12 miles conditions are about the same. There is no railroad on the Armstrong County side of the river and all activity in coal mining is carried on across the river at Monterey, Hillsville, and Catfish. The Lower Clarion is the chief coal mined and the Lower Kittanning bed is also mined. The Vanport limestone remains about 280 feet above the river. Any clays to be developed along that stretch of the river would therefore be 250 to 300 feet above the stream.

Below this, at the great entrenched meander or loop in the river known as Bradys Bend, excellent exposures of the entire Allegheny group are to be seen and about 200 feet of the underlying Pottsville and Pocono rocks. A syncline in that region brings the Allegheny group nearer the stream than normal. The high river banks and the gorge of Sugar Run furnish very good exposures. The Pottsville and Pocono strata seem more shaly than at Parkers Landing. The Allegheny group carries several clays under the Freeport coal but most of them contain iron nodules. Up Sugar Creek, as before noted, the Upper Kittanning Brick Company successfully use the Clarion clay which is from 6 to 11 feet thick. It apparently is the best clay in the section and should be found about 230 feet above the river.

Thence down the river to Red Bank little change is noted in the section and on account of lack of railroad little development of coal or clay is found. At Red Bank the Pottsville rocks are prominent and massive; the Vanport is high above the stream and is about 10 feet thick. Below Red Bank both banks of the river are in Armstrong County. Coal is mined along the east side on the Pennsylvania Railroad, the principal coals being the Lower Kittanning and the Brookville. One mile below Rimer the Kellersburg antiform crosses the river and the rocks are raised so that the Vanport limestone is 450 feet above the river and a greater part of the Burgoon sandstone is exposed along the river. At the Riverview mine two miles below Red Bank 135 feet of Burgoon sandstones and greenish shales are seen. The top of the Burgoon or Pocono rocks rises from Red Bank southward toward the Kellersburg axis and at Rimer is 260 feet above the river. To the south it descends and reaches water level between Mahoning and Templeton. The dip in that region is about 150 feet per mile. At the mouth of Mahoning Creek exposures of a thin coal and sandy shales and sandstones are to be seen, probably in the Pocono, but nothing of value as clay is present.

South from Mahoning the strata dip to the southeast and at Templeton the Pocono series has passed below water level. Here the Harbison Walker Refractories Company operates a well equipped plant for the manufacture of fire brick. The Clarion clay is mined from an opening above the plant and it shows 3 feet of soft bond clay underlain by 8 to 10 feet of harder shaly clay of lower grade. The upper plastic clay is used as a bond with Clearfield County flint clays in making high grade fire brick while the lower material is mixed with the plastic in the manufacture of fire brick of lower heat duty. Sample 192 is from the face and includes both types of clay. It has fair

plasticity and low green strength. It fires cream-buff with a burning range of cone 02 to 11 and fuses at cone 27. It seems suited to the manufacture of fire brick, sewer pipe and face brick. The plant is equipped with dry presses and auger machines and the ware is burned in two Dressler kilns each 440 feet long. These are fired with coal by automatic stokers and the usual temperature reached is about cone 8 or 9. An excellent description of this modern plant was given in *The Brick and Clay Record* for November 6, 1928.

South from Templeton and across the river at West Mosgrove the Kittanning Buff and Gray Brick Company has a plant which manufactures face brick from the Clarion clay mined across the river from Kittanning.

South from Mosgrove the exposures are of the Pottsville series near the river and of the Allegheny group higher up. The Clarion continues to be the most important bed of clay. About 3 miles north of Kittanning near the mouth of a small valley entering Allegheny River, the Willard Kittanning Brick Company operates a plant for the production of buff face brick. The mine is above the plant in the Clarion clay which is 6 to 8 feet thick. The south side of the mine yields a harder clay than the north side. Sample 159 is a mixture of both about as used in the plant. This has good plasticity and low green strength. It fires to a cream-gray to buff with a firing range of cone 05 to 6 and fuses at cone 20. It is suited to the manufacture of face brick, conduits, and sewer pipe. The ware is burned in 15 round kilns. Above the Clarion coal is a brown shale which, during the excavation of their tracks, was successfully burned into red brick.

One mile south of this plant, and near Ewing, is the plant of the Kittanning Clay Manufacturing Company. Their mine is in Clarion clay 6 to 10 feet thick. The mine has a sandstone roof over which the Clarion coal appears. Still higher on the hill they have opened a mine in the Lower Kittanning coal for boiler fuel. They manufacture gray face brick and by adding some loam also make a buff brick. They fire with gas.

At Kittanning excellent exposures of the entire series are seen on both sides of the river. There are extreme irregularities in the section at Kittanning, sections only a few hundred feet apart showing great differences. A section made along the bluff opposite Kittanning by the author is as follows:

Section in river bluff opposite Kittanning

	Feet
Illinoian gravel on high terrace	10
Heavy sandstone, shaly at base	30
Middle Kittanning coal, parting in the middle	1½
Dark clay	1
Blue clay	4
Nodular, semi-flint clay	2
Sandy shale	15
Thin black and rusty shale	12
Lower Kittanning coal	2
Clay	3
Sandstone and shale	3
Clay	3
Olive shale	25
Vanport limestone, an iron ore at top	8
Dark rusty shale	15
Sandy shale	5
Clarion coal	1

	Olive shale	3
	Clay	4
	Shale	14
	Sandstone	4
	Dark shale	3
	Sandstone and shale	4
	Craigsville coal	$\frac{1}{3}$
	Clay	3
	Sandy clay	3
	Dark shale and sandstone	25
Brookville coal	{ Cannel shale or coal	1
	{ Black shale	2
	{ Coal	$\frac{1}{4}$
	{ Dark shale	1
	{ Coal	1
	{ Clay	2
	{ Coal	$\frac{1}{2}$
	Clay	1
Top of Pottsville		

This indicates the general position of the clays in the Kittanning region. The two of most importance are the Clarion and the Lower Kittanning. The Lower Kittanning clay is above water level throughout the district; the Clarion clay drops below rail and water level just south of the city. Two blocks east of the railroad station in Kittanning the Continental Clay Products Company operates a mine and brick plant. This was formerly the Kittanning Clay Manufacturing Company and has been in operation for many years. The quarry shows the following section:

Section in quarry at Kittanning.

	Feet
Dark clay shale	22
Lower Kittanning coal	3
Clay	10
Shale	10
Vanport limestone with iron ore at top	8
Shale and sandstone	30
Clarion coal, very thin	..
Clarion clay	8

Formerly the upper shales and the Kittanning clay were used in the manufacture of face brick, drain tile, paving brick, and some fire brick. Analyses of them are given in the tables. At present the Clarion clay is mined through a shallow shaft for the rocks below the Vanport are not exposed. The product made is light buff face brick. They are burned in 13 round kilns, fired with gas. Lower Kittanning and Clarion clay have also been mined across the river and shipped to other localities. At present the Clarion bed is preferred on account of its greater thickness. The light-colored face brick from the Kittanning region have achieved a high reputation.

South from Kittanning the Allegheny group is exposed on both banks of the river and through several industrial cities. At Manorville, just below Kittanning, about 125 feet of the Allegheny group are above water level, including the Freeport and the Upper Kittanning horizons. The better clays are thus below water level. South from this point the southerly dip tends to throw more of the group below the surface but the curves in the river allow exposures of strata as low as the Lower Kittanning coal in some portions. At Ford City about 110 feet of the group are to be seen. At the time of the construction of

many of the brick buildings there for the Pittsburgh Plate Glass Company two brick yards were in operation, G. B. Dougherty & Sons, and the Manor Brick Company. The section in the quarry of the Manor Brick Company was as follows:

Section in quarry at Ford City.

	Feet	Inch
Limestone	8	
Clay and shale	3	
Coal		2
Clay	10	
Blue-gray shale	20	
Coal	2	
Clay	8	

The limestone probably is the Upper Freeport limestone, the upper clay the Bolivar, and the lower clay the Lower Freeport. The plant used the 10-foot clay and the shales and made red building brick.

Thence south through Rosstown, Logansport, Glen and Kelly, the exposed rocks are sandstones and shales between the Lower Kittanning coal at the base and the Upper Freeport at the top of the bluffs. At Kelly the Lower Freeport coal is at track level and the Upper Freeport 55 feet above. Shales from these horizons might be made into red brick and the clays accompanying the Freeport coals might be used for light-colored brick and fire brick. In this region these clays are often plastic fire clays of good quality but the good clay is thin. Just north of Johnetta the Johnetta Brick and Coal Company formerly operated a plant for the manufacture of light-colored hollow tile. The company mined the Upper Kittanning coal and took out its underclay as the source of their clay. South from Johnetta, through Schenley, Kiskiminetas Junction to Garvers Ferry and Freeport the available strata are chiefly of the Freeport division. At Garvers Ferry opposite Freeport clays of the Freeport horizons are visible in the cliffs but are thin and have not been worked. Half a mile above the bridge at Garvers Ferry a clay was noted which is probably the Lower Freeport. Its thickness was not determined but it is probably about 3 feet. This clay (No. 116) shows a fairly good plasticity and fair green strength. It fires to light cream to buff with a firing range of cone 07 to 13, and fuses at cone 20. It seems suited to the manufacture of buff face brick and fire proofing.

In Freeport the Freeport coals and clays outcrop, the Upper Freeport coal being about 135 feet above the river. Still higher the Mahoning sandstones appear and above them clays belonging to the Brush Creek horizon. The Freeport Brick Company has a brickyard on Buffalo Creek in the north part of Freeport. Above the plant the Lower and Upper Freeport coals are visible, the Upper Freeport bed being mined. A bed of clay 8 to 10 feet thick and 110 feet above this bed is mined for use in the brick plant. Although no Brush Creek limestone could be found it is thought that this is the Brush Creek clay. It is a mottled gray and purple clay. Sample 190 of this clay has good plasticity and fair green strength. It fires to a light buff with a firing range of cone 02 to cone 6. It fuses at cone 26. The company has made red brick from the overlying shale and buff face brick from the clay, but at present they make fire brick. The clay seems well suited to the manufacture of face brick or low heat duty refractories. The Brush

Creek horizon often has thick clays accompanying it which range from face brick clays to refractory clays. It is well to keep this in mind in this region because the Brush Creek horizon outcrops in the higher levels of the hills along Allegheny River for many miles.

REDBANK CREEK VALLEY

Red Bank Creek forms the north boundary of the county. It is a deep, rugged, winding valley and is followed by the so-called Low Grade division of the Pennsylvania Railroad. From its mouth up as far as Climax the creek flows on the Pocono (Burgoon) sandstones and shales and the higher valley walls are of the Pottsville series. Allegheny group coals are sometimes mined but it requires long aerial trams or inclines to bring the coal down to the river. The Burgoon is made up chiefly of cross-bedded sandstones, occasionally with beds of greenish or dark shale.* It probably carries no shales or clays of any great importance. At St. Charles the McLain Fire Brick Company operates a large fire brick plant. The clay used is obtained from a drift mine half a mile west of the plant and on the south side of the creek. The mine opening is about 300 feet above the stream and is believed to be in a Mercer clay in the Pottsville group. The roof and floor of the mine are sandstone and a thin coal streak appears above the clay. The bed consists of about 2 feet of plastic clay underlain by 8 to 10 feet of flint clay. The entire bed ranges from 8 to 12 feet thick and seldom is less than 3 feet thick. Sandstone rolls in places cut out some or all of the clay for short distances. The distribution of the flint and plastic clay is irregular, and it is thought that the bed is not continuous with the bed at Climax. Sample 193 is an average of the material mined. It has, of course a low plasticity and low green strength. It fires to a buff body with a firing range from cones 1 to 10 and fuses at cone 30. It is a high grade flint clay and by mixing the plastic top clay with the other the proper mixture for the brick is obtained. The brick are fired with gas from the companies wells.

At Climax, about two miles up the valley, the Climax Fire Brick Company has a large fire brick plant manufacturing various types of refractories, especially tuyeres. Two units are in operation, one on the north side of the creek in Clarion County, the other on the south side in Armstrong County. Their clay is obtained from openings one mile east of the plants on both sides of the creek. The clay is presumably the Mercer bed, the same as at St. Charles but it is thought to be in discontinuous lenses. It has about the same thickness as the clay at St. Charles and is subject to the same irregularities except that the overlying thin bed of coal is somewhat more regular. The clay is a high quality flint clay.

These are the only openings on the Mercer clay along the valleys. In early days Kier Brothers worked the same bed in the loop of the creek south of the railroad tunnel at a point where the clay was but 75 feet above the river. An analysis of this clay is given in the tables. The bed was said to be about 2 to 4 feet thick and to be a good quality hard clay. These lenses of Mercer clay are irregular but are of large size at St. Charles and Climax. They have been mined for many years. Whether there are any other lenses is uncertain.

Up the valley from Climax the stream makes a great bend to the south, the Pocono beds are brought below water level, and the Pottsville

rocks lie along the stream. As the loop returns to the north some Pocono is again exposed but in the vicinity of New Bethlehem, Oak Ridge and Hawthorne the Fairmount syncline throws the Pocono and the Pottsville below water level and brings down the lower Allegheny group. Three-quarters of a mile west of New Bethlehem the bottom of the Allegheny group lies about 75 feet above the stream and the upper Pottsville at stream level. Here, on the Clarion County side, the shale and clay below the Clarion coal have been worked for hollow tile manufacture.

The Clarion clay shows 5 feet of soft clay underlain by 5 feet of harder, more sandy material (see Clarion County). The Lower Kittanning clay is persistent and 3 to 7 feet thick but has not been developed. At Fairmount, Oak Ridge, and Hawthorne the Vanport limestone is only a short distance above track level and the Lower Kittanning and Clarion clays should be available. At Hawthorne the Middle Kittanning clay has been stripped and used at a pottery now abandoned. It showed 4 to 6 feet of clay, the upper part plastic, the lower part sandy. At Mayport F. B. Pope mines the Lower Kittanning clay and ships it to various plants. From these activities on the Clarion County side of the river it would seem that there are chances of uncovering similar clays on the Armstrong County side.

MAHONING CREEK VALLEY

Mahoning Creek flows from the eastern edge of the county and enters Allegheny River at Mahoning. It has carved a deep, rugged trench in the Allegheny, Pottsville, and Pocono strata, through Eddyville, Putneyville, and Mahoning Furnace. Near the mouth of the creek the rocks are elevated under the influence of the Kellersburg anticline so that the upper Pocono and the Pottsville make the walls of the valley. In the vicinity of Mahoning Furnace the Fairmount syncline brings down the Allegheny group and throws the heavy sandstones of the Pottsville and Pocono series below creek level. Farther up, at Eddyville and McCrea Furnace, the Greendale anticline again brings these heavy sandstones up into prominent onterops again. At McCrea Furnace an eight foot sandy limestone is believed to represent the Mercer limestone. Over much of the valley the Lower Kittanning and Clarion clays are present but have never been worked. In the Mercer horizon there is a possibility of finding lenses of the Mercer clay such as are present at St. Charles and Climax. The valley is served by the Pittsburgh, Shawmut & Northern Railroad, and coal mining is the principal industry.

PINE CREEK VALLEY

The north and south branches of Pine Creek cross the county from the east and enter Allegheny River at Mosgrove. The Buffalo, Rochester & Pittsburgh Railroad follows the south branch eastward from Mosgrove to Dayton and beyond. This valley is much less rugged than Red Bank Creek or Mahoning Creek because its course is almost entirely in the Allegheny group of strata. It cuts down into Pottsville strata only in a two mile stretch just below Oscar, on the crest of the Greendale anticline. Near Dayton the strata are of lower Conemaugh age with the Brush Creek horizon at the surface. The Vanport limestone is somewhat above stream level from Echo down to Pine Creek Furnace and in that stretch the clays of the Brookville, Clarion, and

Lower Kittanning horizons should be available. Above Echo and below Pine Creek Furnace the clays and shales of the upper Allegheny group and those of the lower half of the Conemaugh group could be worked. As far as known clay has not been mined along the Pine Creek valley.

COWANSHANNOCK CREEK VALLEY

The Cowanshannock flows across eastern Armstrong County, through Rural Valley, Yatesboro, and Greendale, and joins Allegheny River at Gosford. The valley has no railroad facilities except at and near Yatesboro which is served by the Rural Valley Railroad coming in from Echo. The Cowanshannock valley is bordered largely by hills of soft shale. Its bottom is a series of alluvial plains. The hills on either side are of Allegheny strata as far up as Yatesboro, beyond which the rocks are chiefly of Conemaugh age. Coal is mined extensively at Yatesboro and Rural Valley, chiefly from the Upper and Lower Freeport beds. No use has been made of the underclays in this area. Five miles east of Kittanning on the Rural Valley road and near Stone House a roadside exposure shows 9 feet of good plastic clay. This may be the Clarion clay. The sample (No. 187) has good plasticity and low green strength. It fires to a cream to gray color with a firing range from cone 03 to 6. It fuses at cone 27. This is an excellent plastic fire clay and is suited to the manufacture of face brick, refractories and sewer pipe. Half a mile north from the junction of the Rural Valley road and the road to New Bethlehem (Route 66) and on the north side of Cowanshannock Creek a small coal mine has been opened.

Section at a coal mine 2½ miles east of Kittanning

	Feet
Sandstone	..
Coal	4
Concealed	6
Plastic clay	2
Flint clay	2
Plastic clay to road	6

This may be the Upper Freeport coal and clay. Sample No. 188 is of the flint clay portion which looks somewhat iron-stained. Its plasticity and green strength are low. It fires to a buff with a firing range of cones 1 to 11 and fuses at cone 29. It is suited to the manufacture of refractories and might well be made into various products by combining it with the plastic clays which overlie and underlie it. These two localities indicate that there are good clays in the Cowanshannock valley east of Kittanning.

CROOKED CREEK VALLEY

Between Cowanshannock Creek and the valley of Crooked Creek is a rolling upland underlain largely by Conemaugh strata. These hills are high enough to catch some of the red clays and shales of the middle part of the Conemaugh group, but most of the exposures are shales and sandstones of the lower part of the Conemaugh group. Exposures are seen at Blanket Hill, Whitesburg and Elderton. Plenty of good brick shales lie in this upland but it is given over to agriculture and there is little demand for brick. The valleys of Cherry Run and Plum Creek drain part of this upland and they have cut down into the upper

Allegheny group, exposing the Freeport coals and elays. Crooked Creek rises east of the county and flows through it from South Bend and Idaho on the southeast border, in a northwesterly direction, through Kirby and Cochrans Mills to Allegheny River at Rosston. It follows a very winding course and has cut deep rocky gorges which alternate with more gentle stretches. Along the bottom lands are low gravel terraces and flood plains. Practically all of its course is cut in the Allegheny group. No railroad uses this valley and this has hindered development of its coals and elays.

Above Idaho the stream flows near the horizon of the Upper Freeport coal and this coal outcrops at the mouth of Plum Creek. The valley walls are chiefly in the lower Conemaugh, including the Mahoning and Brush Creek formations. West from South Bend the rocks rise rapidly toward the axis of the Roaring Run anticline and in succession the Freeport coals, the Kittanning coals, and the Vanport limestone appear in the three mile stretch to Girty. The section shows a 3-foot elay above the Mahoning sandstone (probably Brush Creek horizon), poor elays in the Upper Freeport and Bolivar horizons, and good clay below the Lower Kittanning coal. Just above Girty the Lower Kittanning clay consists of 4 feet of impure clay underlain by 3 to 5 feet of plastic clay. This is in turn, underlain by 25 feet of shales down to the top of the Vanport limestone. The better portion of this elay was formerly manufactured into stoneware at a pottery at Girty owned by McNeese & George. It outcrops for about a mile along the stream. It lies on the crest of Roaring Run anticline which here seems to be split so that just below this exposure the elay passes below stream level and then reappears again in a short exposure of $1\frac{1}{2}$ miles, two miles below Girty. At Girty heavy sandstones above the Lower Kittanning coal are prominent. Below this second outcrop of the clay it passes below stream level and does not reappear in the lower stretches of the stream. Through Cochrans Mills the rocks seen are the upper half of the Allegheny group capped on the high bluffs by Mahoning sandstone. Report H5 records 10 feet of Upper Freeport elay and 4 feet of Lower Freeport elay three miles below Cochrans Mills, in Carnahan ravine. It also reports good clay at the Bolivar horizon near Tunnelville. Thence to the mouth of the stream at Rosston the Freeport coals are prominent and little is known of the elay resources.

The road from Leechburg to Kittanning crosses Crooked Creek about 5 miles above its mouth. South of the bridge is a high hill known as Cooks Summit. This is capped by red clay and shale of middle Conemaugh age. On the south slope of the hill the following section was seen:

<i>Section at Cooks Summit</i>	<i>Feet</i>
Dark gray shale	25
Fine grained sandstone	4
Purple shale	10
Clay	$\frac{1}{4}$
Flaggy sandstone	10

Sample 186 represents the 25-foot shale bed. It shows fair plasticity and low green strength. It fires red to brown with a firing range of cones 03 to 4. It could be used for making drain tile and face brick, and is an indication that the lower Conemaugh has in it some good brick shales.

KISKIMINETAS RIVER

Between Crooked Creek and Kiskiminetas River is a rolling upland of Conemaugh rocks with the Allegheny group appearing only along the streams which flow near the crest of Roaring Run anticline. There is no doubt that there is plenty of good brick shale and clay among the rocks of this upland, but there is little demand for it.

Kiskiminetas River is a very important tributary to Allegheny River. It enters the county just above Avonmore, flows past Salina, Apollo, and Leechburg to its mouth at Schenley and Kiskiminetas Junction. It has cut a deep and winding course through Conemaugh and Allegheny strata and shows rugged, steep-walled characteristics where it crosses the anticlinal axes, and lower hills where it passes through synclines. Its southern or Westmoreland County side is traversed by the Conemaugh division of the Pennsylvania Railroad.

Above Salina the river flows in strata of lower Conemaugh age with the Pittsburgh coal in the uplands. Nothing but brick-making shales are to be expected in this area. At Salina (on the Westmoreland side of the river) the Upper Freeport coal rises above water level and as the stream descends toward the mouth of Roaring Run the whole Allegheny group of 300 feet is exposed. This is due to the Roaring Run anticline which crosses the river at or near the mouth of Roaring Run. The importance of the Bolivar flint clay at Salina has been discussed under Westmoreland County. It seems to be a lens or pocket of clay below the Upper Freeport limestone. How far it may extend into Armstrong County or whether or not other deposits may be discovered are unsolved problems. Below Salina the strata rise rapidly so that in one mile the Bolivar horizon is 260 feet above the river; at the mouth of Roaring Run it has risen to the top of the high bluffs 450 feet above the stream. Between Salina and Roaring Run the Lower Kittanning clay is mined at the Foster No. 5 mine of the Hicks Coal Company. This is on the Armstrong County side of the river half a mile below Salina. The clay ranges from 2 to 15 feet thick but the lower part is sandy. Usually only 1 or 2 feet of the best top clay is mined. Sample 191, the upper material, shows good plasticity and fair green strength. It fires buff to gray with a firing range from cone 03 to 6 and it fuses at cone 20. It is used at Salina as a bond clay in fire brick manufacture and has been used alone for certain types of refractories. It might also be used for the manufacture of sewer pipe and face brick. No other clays of value are known in the region. Two miles below Salina, at Truxall on the west side of the river, the Clarion coal is underlain by a thin clay consisting of one foot of good clay and one and a half feet of yellowish stony clay.

Beyond Roaring Run the beds dip northwest and the Allegheny group gradually passes below water level. Just above Apollo the Bolivar clay was used in the early days (previous to 1880) but now no good exposures of it are known. In Apollo the outcrops are of the Upper Freeport coal and the lower Conemaugh rocks, including the Mahoning sandstone and the Brush Creek and Pine Creek limestones. The Brush Creek horizon has yielded good clay for brick making at Valley Camp, Creighton, and Freeport, and similar clays might be expected here.

From Apollo to Leechburg many mines are working the Upper Freeport coal but very little clay accompanies it. At Leechburg exposures

on the south side of the river show that conditions just below the Upper Freeport coal are very irregular and although there are several thin clays within 25 feet below the coal, a workable bed is doubtful. Sample 185, Westmoreland County, shows the character of this clay. At Leechburg about 70 feet of the Allegheny group are exposed and above them the Conemaugh group. Brick shales should be found about 200 feet above the river in that area.

The strata rise down the valley to an anticline at Bagdad where 135 feet of the Allegheny group are seen, exposing beds down to the Upper Kittanning coal. No clays are known in the stretch between Leechburg and the mouth of the river. The Lower Kittanning clay does not rise above water level. The development of the Armstrong County side of the river along its whole length is retarded by the lack of a railroad. Should the project of making the river again navigable be carried out, activity might increase.

Table 6

Physical tests of Armstrong County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slaking minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Max. shrinkage at cone	Fusion point at cone	Best burning range cone	Firing color	Suggested uses
116	23.8	5.4	11	144	13.2	6	20	08-13	Cream to buff	Face brick, fire proofing
159	19.37	5.8	6½	234	5.2	4	20	05-6	Cream to buff	Face brick, sewer pipe, conduits
160	20.8	6.6	14	225	3.7	8	26	4-9	Buff to gray	Face brick or low grade refractories
186	22.1	0.4	18	108	10.9	3	12	02-4	Red to brown	Face brick, drain tile
187	20.8	2.3	8	158	7.1	6	27	02-6	Cream to gray	Face brick, sewer pipe, refractories
188	19.9	2.2	6	169	2.1	3	29	02-11	Buff	Refractories
190	20.5	4.4	11	167	6.0	6	26	02-6	Light buff to gray	Face brick or low grade refractories
191	19.1	4.1	23	162	6.1	3	20	02-6	Buff to gray	Face brick, sewer pipe
192	18.4	1.6	20	160	5.7	6	27	02-11	Cream to gray	Face brick, sewer pipe, low grade refractories
193	15.5	0.5	10	18	5.8	11	30	1-11	Buff	Refractories
194	19.4	5.3	12	111	6.2	6	23	1-9	Buff to gray	Face brick, sewer pipe

Table 7

Chemical analyses of Armstrong County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃	
116	5.84	58.38	3.45	1.76	20.38	1.90	2.59	2.10	1.87	.48	.12	.77	-----
159	4.94	60.66	6.55	-----	-----	.38	2.56	-----	-----	-----	-----	-----	-----
160	7.70	58.60	2.61	.74	25.46	1.08	.44	.42	1.56	.08	.33	.46	-----
186	7.69	59.14	3.60	1.92	18.21	.82	2.29	.33	.51	.15	.12	.29	-----
188	9.40	60.19	13.75	2.09	10.26	2.18	1.65	.46	.36	.21	.50	1.90	-----
190	6.46	60.55	6.20	1.10	22.05	.52	.97	.56	1.90	.01	.06	.20	-----
191	11.22	46.06	6.73	2.46	27.47	.06	1.63	.61	1.03	.05	.06	1.84	-----
192	8.49	54.64	2.45	.99	29.04	.62	1.18	1.02	.24	.002	.89	.43	-----
193	12.27	61.16	1.35	.53	16.71	1.17	3.97	.24	1.69	.20	.29	.42	-----
194	8.01	59.11	7.71	1.34	22.05	.97	.84	.09	.19	.03	.30	.23	-----
								{					FeO
A	13.63	44.61	-----	1.02	38.01	.08	.40	1.73		-----	-----	-----	1.25
B	12.69	55.96	-----	1.01	28.41	.07	.39	.61		-----	-----	-----	1.64
C	13.76	50.37	-----	1.03	32.89	.31	.25	.29		-----	-----	-----	1.64
D	8.11	58.75	-----	1.05	25.17	.71	.93	3.53		Tr.	-----	-----	2.19
E	8.55	53.31	8.75	-----	24.54	-----	-----	-----	-----	.38	-----	-----	-----
F	8.71	60.40	1.34	-----	26.23	.14	.54	2.66	.28	-----	-----	-----	.23
G	6.81	55.17	12.01	-----	19.32	-----	-----	-----	-----	-----	-----	-----	-----
H	8.59	59.80	5.92	-----	19.72	-----	-----	-----	-----	-----	-----	-----	-----

Localities from which samples were obtained.

116. Lower Freeport clay, Garvers Ferry.
 159. Clarion clay, Willard Kittanning Brick Company, north of Kittanning.
 160. Clarion clay, Upper Kittanning Brick Company, Bradys Bend.
 186. Shale along road, south of Cooks Summit.
 187. Clay, 5 miles east of Kittanning on the Sagamore road.
 188. Flint clay under Upper Freeport coal, E. of Kittanning on New Bethlehem Road.
 190. Brush Creek clay, Freeport Brick Company, Freeport.
 191. Lower Kittanning clay, Foster No. 5 mine, Hicks Coal Co., Salina.
 192. Clarion clay, Harbison-Walker Refractories Company, Templeton.
 193. Mercer clay, McLain Fire Brick Company, St. Charles.
 194. Clarion clay, Graf-Kittanning Clay Products Company, Craigsville.
 A. Mercer clay, Kier Bros., south of Climax. Pennsylvania Second Geol. Survey, H5, p. 195.
 B. Lower Kittanning clay, Stewarts mine, Kittanning. Pennsylvania Second Geol. Survey, H5, p. 249.
 C. Lower Kittanning clay, Allegheny Furnace, on Organ Run. Pennsylvania Second Geol. Survey, H5, p. 240.
 D. Clarion clay, Ross Reyno's plant, 1 mi. N. E. of Kittanning. Pennsylvania Second Geol. Survey, H5, p. 246.
 E. Shale above Lower Kittanning coal, Kittanning Clay Mnfg. Company, Kittanning. Appendix to Annual Rept. of Pa. State College for 1897, Clays of western Pennsylvania, p. 123.
 F. Lower Kittanning clay, same locality and reference as above.
 G. Blue shale below Lower Kittanning clay, same locality and reference as above.
 H. Shale below Vanport limestone, same locality and reference as above.

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BEAVER COUNTY

Beaver County lies north of Washington County and northwest of Allegheny County. The topography is governed largely by the deep valleys of Ohio and Beaver rivers. These prominent valleys, divide the county into three distinct areas of upland which we may term the northwestern, southeastern, and eastern areas. They are hilly with hilltops at the general level of a dissected peneplain at 1200 to 1280 feet above sea level. A few isolated hills rise to heights of 1300 to 1380 feet above sea level. Traces of a lower series of levels are found at about 1100 feet which are remnants of the Worthington peneplain. Bordering the Ohio and Beaver rivers and some of their principal tributaries are also to be seen a series of terraces approximately 150 feet above river level. These latter are remnants of an ancient level of the main streams and upon them are deposits of sand and gravel or clay.

The northwest corner of the county is covered with glacial drift left by the Wisconsin ice sheet. Cannelton, Darlington, and New Galilee lie in this glaciated area.

STRATIGRAPHY OF CLAY BEDS

Pottsville Series

The exposed rocks range in age from near the base of the Pottsville series up to the lower Monongahela group. The Pottsville rocks are exposed in the inner gorge of Beaver River from Beaver Falls north to the Lawrence County line and along Connoquenessing Creek from Frisco south and east for several miles. That part of the Pottsville seen has a section about as follows:

Section of Pottsville series on Beaver River

	Feet
Homewood sandstone	30
Coal	1
Fire clay	0-2
Shale with iron nodules	10
Upper Mercer coal a few inches	..
Upper Mercer shales, with iron nodules	20
Upper Connoquenessing sandstone	50

It seems unlikely that any clays or shales of value are to be found in this series.

Allegheny Group

Above the Pottsville series lies the Allegheny group, extending from the Homewood sandstone as a base up to and including the Upper Freeport coal. In Beaver County this group averages about 300 feet thick. The coals, clays, limestones, and sandstones of this group are extremely irregular and it is difficult to construct a generalized section. The principal members and the intervals between them are as follows:

Section of Allegheny group in Beaver County

	Feet
Upper Freeport coal	1- 7
Fire clay, sometimes thickening	3- 5
Shale and sandstone, thin Bolivar clay	60
Lower Freeport coal, averages 15 inches	0- 4
Fire clay, sometimes workable	3- 5
Shale and sandstone	60
Upper Kittanning coal, usually very thin	½-13
Shale	27
Middle Kittanning coal	1- 2½
Fire clay with many iron nodules	4
Dark shale	30
Lower Kittanning coal	1- 3
Fire clay, upper plastic, lower sandy	2-11
Shale and sandstone	50
Vanport limestone	1-20
Shale	20
Clarion coal	½
Fire clay	2- 4
Shale and sandstone	50
Brookville coal	2
Fire clay	2
Shale	10

It will be noted that fire clays have been found in at least seven horizons. Most of them are thin and many exposures show too much iron in the form of limonite or siderite nodules. The coals are generally too thin to be workable and that also militates against the development or the exposure of the accompanying fire clays. The fire clay beneath the Lower Kittanning coal overshadows all other beds in importance and at present is the only bed being worked in the county. Its importance is due to its regularity and thickness, and its position with reference to the railroads and rivers. It almost invariably is 4 to 6 feet of good plastic clay grading down into more sandy material about 5 feet thick. This gives a thickness of 9 to 11 feet if the whole section is used. For the various types of ware made varying amounts of the lower sandy material are used.

The Lower Kittanning clay is exposed along Ohio River from Freedom down to Smiths Ferry; along Beaver River from Beaver to above Beaver Falls; and along such tributaries as Bradys Run and Block House Run. This places it in an unusually favorable position with respect to the railroads which follow these main valleys. In the north-western part of the county the Lower Kittanning clay is again well exposed in the valley of Little Beaver River and is mined at Darlington and New Galilee along the Pittsburgh, Lisbon & Western Railroad and the Fort Wayne division of the Pennsylvania Railroad. Altogether within the county there are exposed about 145 miles of outcrop of this valuable clay. If we assume that this material could be mined back from the outcrop half a mile this would give an area of 72 square miles of accessible clay. Assuming a general thickness of 8 feet of clay over this area and a weight of 120 pounds per cubic foot for the clay we arrive at a potential supply of 963,477,504 tons in the county. This does not take into consideration much clay deeply buried beneath the highlands farther than half a mile from an outcrop, nor does it include any clay below river level which may be mined by shafts. Some of this deeper clay no doubt exists in the upper Ohio valley south of Freedom.

The Upper Freeport clay has been reported as 10 to 22 feet thick at Fallston and 14 feet thick at Georgetown. The Lower Freeport clay is reported as 14 feet thick on Blockhouse Run and was once used there for sewer pipe manufacture. The Clarion clay is reported as a very pure clay but is generally too near river level to be much used.

The shales of the Allegheny group are usually dark and filled with concretions of limonite or siderite, iron compounds which lower the value of the material very much. However, gray shales are available, especially above the Vanport limestone, and these are successfully worked at many places.

The Allegheny group forms the surface rock over most of the northern half of the county.

Conemaugh Group

This group lies above the Allegheny group and forms the surface rock on the uplands of the southern half of the county. The greater part of it is not accessible to railroads and the rocks are not utilized. The group averages about 520 feet thick and shows about the same members as in Allegheny County, perhaps with more shale and less sandstone. The most promising beds of shale in it are the red and green shale beneath the Ames limestone, which are generally 50 to 70 feet thick and similar to those used so extensively in Allegheny County; and a 30-foot bed of yellow and red "eaky" shale below the Brush Creek limestone and coal. This latter is a persistent bed and has been termed the New Galilee clay by De Wolf, who mapped it as a separate unit on the New Castle quadrangle economic geology map. This clay in places takes on a flinty appearance but is too high in iron to be of value as a flint clay.

Between the upper and lower Mahoning sandstones and about 30 feet above the Upper Freeport coal, there is sometimes seen a zone containing a limestone, a flinty clay, and a thin coal, the latter termed the East Palestine coal by De Wolf. The flint clay at this horizon was sampled (No. 158) in the cliff opposite Ambridge and showed fair plasticity and green strength, and fired to a dark buff with a firing range of 1100 to 1300° C. It fused at cone 20. This shows that it is not a true flint clay but it has possibilities as a low grade refractory.

For detailed discussion it seems best to divide the county into districts, the southwest, southeast, northeast and northwest, Beaver Valley, Ohio Valley, Blockhouse Run and Bradys Run.

CLAY RESOURCES BY DISTRICTS

Southwest district. The upland south and west of Ohio River is included in this district. This region is not tapped by railroads and is underlain principally by Conemaugh strata. It is drained chiefly by Raccoon Creek and its branches. Little is known concerning the clay and shale possibilities of this area except that probably there are no true fire clays present and that the best brick clays would be those below the Ames limestone and the Brush Creek horizon, the New Galilee clay. The terrace clays of the Carmichaels formation are present along Raccoon Creek and in an abandoned channel east of New Sheffield but these are generally sandy clays, silts or gravels.

Mill Creek, Peggs Run, Raccoon Creek, Moon Run, and Logtown Run, in their lower courses, cut down into the upper half of the Al-

leggheny group, and afford a possibility of opening the Freeport and the Kittanning fire clays. The Lower Kittanning coal and clay extend up Mill Creek and up Raccoon Creek only a short distance, the outcrop being about 5 miles long. With our usual method of estimation this might yield about 25,983,344 tons of clay. The Upper Freeport coal and clay extend farther up these valleys and the clay is more persistent than the coal. Thicknesses of as much as 14 feet of clay have been reported near the mouth of Mill Creek and 7 feet in the exposures east of Georgetown, but the usual thickness is 3 to 5 feet. In places this is a good clay and elsewhere it is very full of iron nodules. Taking the thickness at the lower figure, 3 feet, with an outcrop of about 40 miles along the streams mentioned, and assuming that the clay is available for half a mile back from the outcrop, we arrive at a supply of 100,362,240 tons of clay. Good exposures of these clays are not available and mining of them has not been attempted. One reason for lack of development of these short valleys is the fact that no railroad has been built along the south bank of Ohio River west of Monaca.

Ohio Valley, south from Rochester. Ohio River enters the county at Ambridge and flows north past Aliquippa and Freedom to Rochester. In this stretch the valley is about a mile wide and is bordered by two prominent gravel-covered terraces, upon which the cities and the railroads are chiefly built. Behind the terraces, the valley walls rise 200 feet or more and in them are exposed rocks of the upper Allegheny and lower Conemaugh groups. The Pittsburgh & Lake Erie Railroad follows the west bank of the river and the Pennsylvania Railroad the east bank, giving excellent rail facilities for any clay or shale developments.

Near Ambridge the lower rocks exposed are the Mahoning sandstone, with the Mahoning clay zone appearing near road level across the river from Ambridge (see sample 158). This material is also seen around Parks Quarries up Crows Run. Higher up on the sides of the valley Conemaugh shales in the Brush Creek horizon might be utilized and by following up some of the small runs, shales still higher in the section might be obtained. This was formerly done about 2 miles up Legionville Hollow, where a brick yard used clay and shale from beneath the Bakertown coal bed.

The Allegheny group rises above river level north of West Economy and at Legionville. Thence north more and more of this formation is exposed as the Freeport coal bed rises above the river. At Freedom this coal is 180 feet and at Beaver 240 feet above the river. This brings to light about 200 feet of the upper Allegheny strata in this region, although much of it is obscured by terrace deposits. Near the mouth of Crows Run the following section is exposed:

Section near mouth of Crows Run

	<i>Feet</i>
Thin sandstone	6
Middle Kittanning coal	1½
Fire clay, shaly in the middle	11
Dark shale	24
Lower Kittanning coal	2
Fire clay, to water level	6

The lower 3 feet of the Middle Kittanning clay at this point was

sampled (No. 165). It shows good plasticity, fair green strength, and burns to light buff with a firing range of 1050 to 1250° C. It fuses at cone 20. This should be suitable for face brick and sewer pipe, and could no doubt be blended with the upper portion which is partly elay and partly shale. The Lower Kittanning clay seen in the section has been mined by a shallow shaft a short distance up Crows Run at the plant of the Pennsylvania Clay Company. The plastic part of the clay bed and some of the more sandy bottom material were taken out. This property is not now in operation. The principal product was paving brick. This elay (sample 166) shows fair plasticity and green strength, burns to dark buff or gray at 1200° C., and fuses at cone 16. It seems suited to the manufacture of face brick as well as paving brick. The plant is equipped with dry pans, a Freese brick machine and represses, drying tunnels and nine round coal-fired kilns. Farther up Crows Run exposures of the Middle Kittanning elays are to be seen and occasionally thin clays of higher horizons. Similar exposures of these two clay seams occur between Conway and Rochester.

At the southern boundary of Rochester, the Rochester Clay Products Company formerly operated a plant for the manufacture of face brick of various shades. This plant was dismantled in 1929.

Section in quarry at Rochester

	Feet
Brown shale	10-15
Lower Kittanning coal	2
Plastic fire clay	3
Sandy clay and sandstone	10
Gray and bluish shale	15

The fire clay (sample 167) has good plasticity and fair green strength. It burns to light buff with a firing range of 1150 to 1250° C. and fuses at cone 20. It could be used for face brick or for low grade refractories. The lower blue shale (No. 168) has fair plasticity and low green strength. It burns to dark buff with a firing range of 1100 to 1200° C. Used alone it exhibits rather poor burning properties but used in conjunction with the fire elay, as was the practice, it made a good grade of face brick.

There are thus in the Ohio valley above its junction with Beaver River at least two elays of some promise, the Middle Kittanning not used, and the Lower Kittanning, used in two plants not now operating. Assuming that these elays keep the same quality and thickness beneath the terraces there is above river level about 8 miles of outcrop in this area. If these elays are workable for half a mile back from the outcrop we would have 4 square miles of available elay. At 3 feet thick this gives for the Middle Kittanning a reserve of 20,000,000 tons. On the basis of a thickness of 6 feet for the Lower Kittanning it would contain 40,000,000 tons.

Southeast district. This applies to the region east of the Ohio Valley above Rochester. It is an upland area not penetrated by railroads. It is drained by Sewickley Creek in the southern part; by Legionville Hollow and Crows Run in the central part; and by Brush Creek in the northern portion. The uplands are all in Conemaugh strata, some of the higher hills extending above the Ames limestone. The most promising horizons for elay production would be the red elays near the Ames

limestone and the yellow and gray clays below the Brush Creek coal. In Legionville Hollow and in Crows Run, the Allegheny group appears. Along Brush Creek from the Butler County line, through Unionville to the mouth of the creek, the Allegheny group is exposed and fire clays no doubt are present. No railroad follows this stream, however, and there has been no development. The Lower Freeport coal in the vicinity of Unionville overlies 2 to 6 feet of fire clay, and the Upper Freeport coal also shows a blossom of whitish clay of about the same thickness. On down Brush Creek below Barnesville the Lower Kittanning fire clay appears and probably could be worked if better transportation were available.

Northeast district. The region east of Beaver River is an upland of Allegheny and Conemaugh strata, the Conemaugh strata lying in the high hills east of Beaver Falls. It drains through short valleys, such as Bennetts Run and Thompsons Run, into Beaver River and is deeply cut by Connoquenessing Creek, which flows from Butler County westward to North Sewickley and Frisco. In the vicinity of these two towns Pottsville rocks are exposed. Clays at the New Galilee, Freeport, and Kittanning horizons are exposed in the region but are usually not accessible on account of lack of railroads. Thompsons Run and Connoquenessing Creek are served by the Baltimore & Ohio Railroad. Between Hazen and Fombell on Connoquenessing Creek the Lower Kittanning clay is exposed with a thickness of 5 to 9 feet, and this seems to be the best place for the development of this bed in the district. Near the eastern border of the county, west of Zelienople, shales with many iron nodules are frequently seen along the trolley line and the Baltimore & Ohio Railroad. These probably are at the horizon of the Middle or Upper Kittanning beds. Tests of this material from Butler County indicate that it is of little value for ceramic purposes. East and north of Fombell a thin coal, probably the Upper or Middle Kittanning, is to be seen and beneath it there is usually 2 to 3 feet of low grade fire clay similar to that at Isle (see sample 117).

Southwest of Zelienople, along the Rochester road, and northeast of Burry School good exposures of shale were noted. Sample 203 represents the mixture of 10 feet of gray shale and 10 feet of an underlying darker blue shale at this place. This shale shows good plasticity and low green strength. It burns to red or brown with a firing range of 1050 to 1150° C. and is suitable for the manufacture of brick and tile.

Farther down Connoquenessing Creek the Lower Allegheny strata are exposed, the Vanport limestone is quarried, and the Brookville and Clarion clays might be uncovered. Near Frisco the Clydesdale Brick and Stone Company is manufacturing paving brick from shale immediately above the thick Vanport limestone which was formerly mined. This shale is 15 feet thick. Tests on a sample of it (No. 179) show that it has good plasticity, low green strength, and that it burns to dark brown with a burning range of 1050 to 1250° C. It might also be used in the manufacture of face brick. Above the shale the Lower Kittanning fire clay is exposed with a thickness of about 5 feet. Sample 178 represents this clay. It has good plasticity and high green strength. It burns to a cream to dark buff color with a firing range of 1150 to 1350° C. and fuses at cone 20. This gives it the qualities suited for the manufacture of low grade refractories, sewer pipe, and face brick.

It is estimated that in this area there are about 21 miles of outcrop

of the Lower Kittanning coal and clay along Connoquenessing Creek, Brush Creek, and the minor streams. Assuming a thickness of 5 feet for the clay we would place the deposit of available clay at 85,192,225 tons. Other clay beds in the region have not been estimated.

Beaver River Valley. This broad valley represents an early glacial stream; the inner gorge has been cut by the present stream. The valley therefore consists of the narrow inner gorge, broad terraces of the older stream, and the old valley walls beyond the terraces. The inner gorge is followed by the Pittsburgh & Lake Erie Railroad on the west bank and the Pennsylvania Railroad on the east bank. It is carved chiefly from Pottsville rocks and shows no materials of ceramic value. The higher flat terraces are followed by another branch of the Pennsylvania Railroad along the west side of the valley. The terraces are chiefly covered by sands and gravels of glacial origin and Illinoian age. The slopes back from the terraces show good exposures of the Allegheny group from the Brookville horizon at the base to the Freeport coal horizon near the top of the slopes. The Vanport limestone and the overlying Lower and Middle Kittanning coals and their clays lie only a few feet above the road and railroad along the terrace from the north border of the county nearly to Beaver Falls. This makes these clays and the shale above the Vanport limestone very easily accessible. From Hoytdale down to the northern borders of Beaver Falls no use has been made of any of these clays. In the northern end of Beaver Falls the Wilcox brick yard formerly used a clay shale at the Brookville horizon. Across the river in Eastvale the Pittsburgh Clay Products Company mines the Lower Kittanning clay and also, quarries various shales above the Vanport limestone and some below, probably between the Clarion and Brookville horizons. The section shown there is as follows:

Section at Eastvale

	Feet
Brown shale	10
Lower Kittanning coal	2
Soft fire clay	5
Sandstone	1
Drab sandy shale	5
Light buff shale	15
Dark thin gray shale	15
Vanport limestone	2
Shales and concealed	40

The material mined and used in face brick manufacture at present is the fire clay and some of the more sandy material beneath it, giving a mined thickness of 11 feet of clay. The 30 feet of shale just above the Vanport limestone is of less value. Sample 176 represents an average of it. The plasticity is good but the green strength rather low. It fires to a good red color either light or dark, but has a short firing range of 1100 to 1150° C. Formerly these shales with some of those below the Vanport limestone were used in making red brick but now only the fire clay is used and the product is buff face brick. The clay is carried from the mine to the plant by bucket conveyor. The plant is equipped with two dry pans, Freese auger brick machine, Steele cutter, and ten round and two square kilns fired with coal.

Thence down through New Brighton the rocks exposed along the rail-

road belong to the Brookville-Clarion group, below the Vanport limestone. Thin coals and dark shales predominate but two fire clays were seen, possibly representing the Brookville and the Clarion clays. The upper one is 4 feet thick and the lower one 2 feet thick.

Along Beaver Valley then the principal bed of clay is the Lower Kittanning and it has an outcrop of approximately 37 miles, including the portions which extend up the small side streams for a short distance but not including the exposures on the larger streams, as on Blockhouse or Bradys runs. With our usual mode of calculation and assuming a 5-foot bed of soft clay and a 5-foot layer of more sandy material we have the following tonnage for the valley; soft clay 150,100,582, sandy clay, 150,100,582, or a combined deposit of 300,201,164 tons.

Blockhouse Run. This stream rises east of Beaver Falls and flows west and south, entering the Beaver River south of New Brighton. Through the eastern part of New Brighton its valley is the site of numerous clay plants and it may be discussed as a unit. Through New Brighton its eastern bank exposes strata from below the Vanport limestone up to and above the Upper Kittanning coal bed. The Lower Kittanning clay bed is the most important horizon and this is in an excellent position for exploitation. Terraces covered with gravel and clay lie above the exposed strata and extend along the valley as a distinct shelf.

Going up the valley, the first plant encountered is the W. H. Elverson Pottery Company. This company began operations in 1862, using the Lower Kittanning clay. At present they use terrace clays hauled from a high terrace to the east, mixing about three parts yellowish sandy clay with one part very stiff drab clay. Occasionally some Lower Kittanning clay is added. The clays are mixed in a battery of heavy blungers, molded on jolly wheels, and burned in down draft kilns. The product is flower pots of an even light red shade. Sample 171, the usual mixture, has good plasticity, and an unusually high green strength, the modulus of rupture of the neat mixture being 765 pounds per square inch. It fires to a good red with a range of 1000 to 1150° C. and fuses at cone 14. It makes excellent flower pots and by blending with less plastic clay or shale could be made into face brick or sewer pipe. This is one more instance of the excellent quality of some of the plastic terrace clays of western Pennsylvania.

The next plant up the valley is the Sherwood Brothers Pottery at 13th Street. This company manufactures crocks and other stoneware from the Lower Kittanning clay mined in the hill just east of the plant. It mines 6½ feet of the upper and better portion of the bed and leaves the coal as a roof. The clay is allowed to weather for some time to increase its plasticity or it is mixed with weathered clay from the outcrop. This plant is also one of the oldest in the district.

A few blocks north of the Sherwood plant is the brick yard of the A. F. Smith Company. This yard is not now in operation but formerly made dark-red, soft-mud brick from the shales overlying the Lower Kittanning coal. The company operates two clay mines near the plant, mining the Lower Kittanning clay bed. This bed is 6 to 11 feet thick but as usual the lower part is sandy or shaly. The clay is shipped to local buyers or in some cases shipped as far away as St. Louis.

Continuing up Blockhouse Run three-quarters of a mile, the next plant encountered is that of the Brighton Fire Brick Company on the west side of the valley and railroad. The material used is the Lower Kittanning clay which is mined from an opening 30 feet above the plant. The whole section of about 10 feet of both the plastic upper and the sandier bottom is used. Just beyond, to the northeast, is the Brighton Clay Products Company who make red hollow tile. The material used is the shale above the Lower Kittanning coal, including a 2-foot bed of the Middle Kittanning clay. Originally the Lower Kittanning clay was used, then a mixture of the shale and this clay, but at present no Lower Kittanning clay is used in their ware.

Across the railroad from the plant just mentioned is the plant of the American Vitified Clay Products Company. They manufacture "hot tops" for ingot molds and other fire clay shapes, using the Lower Kittanning clay. The clay is obtained from a 40-foot shaft half a mile up the valley. Coal and clay are both obtained from this shaft and are carried to the plant by a horse tram. The ware are burned in 12 down-draft kilns. This plant was formerly the property of the American Sewer Pipe Company and sewer pipe were manufactured extensively. At that time some of the Darlington clay outcropping above the plant was also used.

Up the valley from these plants the Lower Kittanning clay passes below stream level and the Upper Kittanning and Freeport horizons appear. The Upper Freeport clay was at one time used here for paving brick manufacture but at present none of the clays are used in the upper part of the valley. Assuming a thickness of 6 feet for the Lower Kittanning clay the entire Blockhouse Run Valley would probably yield 19,472,508 tons of clay in this bed. The other Kittanning clays and the Freeport clays are of less importance in the valley and are found principally in the upper end. It is possible that they might yield about 4,000,000 tons of clay.

Bradys Run. This stream joins Beaver River below Fallston and its valley extends northeast. As in Blockhouse Run, the Lower Kittanning clay and clay beds above and below it are well exposed and the valley has long been the site of numerous clay-working enterprises. Potteries and fire brick works have in the past been in operation in the valley near Fallston but all these are abandoned and in their place three well equipped face brick plants operate. These are about half a mile up the stream from Fallston and in order from Fallston are the Colonial Clay Products Company, Continental Clay Products Company, and Standard Clay Products Company. All three manufacture buff face brick and other shades of brick from Lower Kittanning clay mined near the plants. Shale is often mixed with the clay to modify the shade; in the earlier plants some of the Darlington or Upper Freeport clays were also used in the mixtures. The Lower Kittanning clay continues at a convenient height above the valley bottom for about 5 miles up the branches of the valley and it would seem that there is an almost unlimited supply for the manufacture of various clay products.

The Lower Freeport clay in this region is only 2 feet thick and the Upper Freeport is also usually thin and iron-stained. Below the Lower Kittanning clay, near the mouth of Bradys Run, the Clarion clay is exposed and was at one time worked by the Fallston Pottery Company. It has been said that this clay is 6 to 10 feet thick and purer and lighter

burning than the Lower Kittanning. However, exposures of what seems to be the Clarion clay on Bradys Run and along the railroad near Fallston show thicknesses of 3 to 4 feet. The Clarion clay may be worked at some time in that vicinity or it might be reached by shafts at points farther up the valley.

The outcrop of the Lower Kittanning coal and clay extends for several miles up the south and north branches of Bradys Run and in the entire valley has an extent of about 24 miles. With a thickness of 6 feet and assuming that the clay could be mined half a mile back from its outcrop this would give 116,835,048 tons of clay as the possible supply. Tonnage in the other beds seems impossible to estimate.

Northwest district. The region west of Beaver River and north of Ohio River is an upland of Conemaugh in the south and of Allegheny strata in the north. The upland is dissected by many short valleys which drain into the Ohio and Beaver rivers. These valleys, like Bradys Run, expose the Lower Kittanning coal and clay in their lower course and the Upper Freeport horizon nearer their headwaters. In the northern part of the area the dominating feature of the topography is the low, wide valley of Little Beaver River. This is followed by the Pittsburgh, Lisbon & Western Railroad west from New Galilee and by the Pennsylvania Railroad (Fort Wayne Div.) through New Galilee and down Clarks Run to Beaver River. In the northern area only the higher hills carry the Conemaugh group and only that part of the Conemaugh below the Ames limestone is present. The most important horizons are the clay below the Brush Creek coal and limestone, called here the New Galilee clay, and the clay in the Mahoning horizon, called the East Palestine clay.

The New Galilee clay is orange-brown, with an appearance at some places of flint clay. It is never, however, a flint clay or even a real fire clay, being too high in iron. It ranges from 6 to 20 feet in thickness and where readily accessible may be used for the manufacture of brick.

The East Palestine clay lies beneath the East Palestine coal. Near East Palestine, Ohio it is a plastic clay, used for making fireproofing, conduits, sills, drains, etc.

In northwestern Beaver County it has been noted with thickness of 2 to 9 feet. In the coal stripping of the White Clay Mining Company south of Cannelton, much of this bed was exposed and the Darlington Fireproofing Company is now taking it from the old stripping pits. The clay is here from 5 to 7 feet thick, averaging about 6 feet. A sample (No. 173) shows good plasticity and fair green strength. It burns to red or gray-red with a firing range of 1000 to 1200° C., and fuses at cone 13. It seems suitable for the manufacture of face brick and drain tile. It is stripped and trammed to a tipple from which it is carried down to the plant in the valley. This is connected to the railroad by a spur extending up a branch of Painters Run.

Most of the Conemaugh group is inaccessible to the railroads and will not soon be developed.

The development of the clays and shales of the Allegheny group and in fact the only development in the Northwest District, is in the Little Beaver Valley between New Galilee and Cannelton, along the railroads already mentioned. In the walls of this low, flat-bottomed valley the Lower Kittanning clay is exposed in a long outcrop, making it accessible over a large territory.

Just south of New Galilee the Beaver Clay Manufacturing Company mines the Lower Kittanning clay, taking out the upper 8 or 9 feet of a 12-foot bed. Twenty feet above the clay and coal there is also a 15-foot bed of shale which has been used for red brick manufacture. At present the fire clay is used exclusively and the product made is buff face brick. The shale (sample 174) shows fair plasticity and low green strength. It burns to a poor red to black with a firing range of 1050 to 1200° C. The Lower Kittanning clay (sample 175) has fair plasticity and fair green strength. It burns to light buff to gray and has a firing range of 1100 to 1300° C. It is suitable for the manufacture of low duty refractories and face brick.

Just west of Darlington several plants are operating on the Lower Kittanning clay. The nearest one is the plant of the Fiske Company. Clay is mined from the hill just north of the plant. About 8 feet of the bed is used but this amount varies as different shades of brick are required. The product made is chiefly buff face brick. The clay (No. 172) has fair plasticity and rather low green strength. It burns buff to gray with a firing range of 1150 to 1350° C. and fuses at cone 20. It could be used in making low duty refractories as well as for the present use in making buff face brick. The plant is one of the most modern in the State, and the burning is done in tunnel kilns.

The next plant is that of the Darlington Brick and Mining Company on the south side of the valley. They mine Lower Kittanning clay in a bed 8 feet thick and take out the overlying coal which is 30 inches thick. The coal is used in the drying tunnels. The ware, which is buff brick, is burned in a battery of nine kilns, two of which are coal-fired and seven are gas-fired.

One quarter mile west is the No. 3 plant of the Alliance Brick Company. This company manufactures hollow tile, burning in 14 round kilns fired with producer gas. The clay used is the Lower Kittanning which as usual shows about 3 feet of plastic clay underlain by 8 to 10 feet of more sandy and shaly clay. For the purposes of this plant about one part plastic clay and three parts sandy bottom material are used.

Little attention has been paid to the clays above the Lower Kittanning bed. They are known to be thinner and not as readily accessible.

In this Northwest District there is apparently about 34 miles of outcrop of the Lower Kittanning clay, exclusive of the exposures along the Beaver and Ohio rivers. Assuming a thickness of 6 feet for it and calculating in the usual way we compute a deposit of 165,516,318 tons. The other clays such as those of the Conemaugh group and the Allegheny clays above the Lower Kittanning will no doubt add considerably to this tonnage in the future but no estimates can be made of them at present.

Ohio Valley west of Beaver. West from Beaver the Ohio flows in a deep valley lined with gravel-covered terraces, back of which the valley walls rise 400 to 500 feet, exposing practically all of the Allegheny group. The Lower Kittanning coal and its clay outcrop near river level, near the edge of the terraces, or are buried beneath the terrace gravels. The Upper Freeport coal and clay appear near the top of the bluff or extending several miles up the tributary streams. The available shales and clays would thus be confined to the strata between the Upper Freeport coal and the Lower Kittanning clay. As in other parts of the county the Lower Kittanning clay is the most valuable and is at

present the only clay worked along the river. Operations are confined to the north bank of the river as there is no railroad on the south side.

The first plant west from Vanport is the abandoned plant of the Vanport Brick Company, which in the past mined the Lower Kittanning coal and clay and also used the shales above the coal bed. At different times the plant used the clay for fire brick manufacture and the clay and shale mixture for making building brick. The section exposed in the quarry is as follows:

Section in quarry at Vanport

	Feet
Heavy sandstone	10
Middle Kittanning coal	1
Black shales	10
Nodular shales	20
Lower Kittanning coal	1¼
Lower Kittanning clay	9
Heavy sandstone	25
Vanport limestone	7

Just beyond (to the west) the Gloninger & Company plant makes water-proof brick and fire brick. Lower Kittanning clay and coal are mined back of the plant. The section is similar to the one given above, and the plant is built upon the Vanport limestone.

One mile beyond, at Dam No. 6 or Merrill is the Dando plant of the McLain Fire Brick Company. Fire brick are manufactured from the Lower Kittanning clay which is mined directly back of the plant and above the sandstone in the Vanport section. A sample of the ground clay (No. 177) has good plasticity and develops high green strength. It burns buff to gray with a firing range of 1100 to 1300°C. and fuses at cone 27. It is suitable for refractory products or for face brick. The clay at those plants averages about 6 feet thick but if more sandy material is desired a greater thickness can be removed.

Thence to the Ohio line the clay is alternately exposed and covered by terrace material. There seems to be ample opportunity for its development for many miles.

The Lower Kittanning clay bed has an outcrop about 38 miles long in the valley and if the clay is considered to have a thickness of 6 feet the total deposit within half a mile of the outcrop should be 184,988,826 tons.

Table 8

Physical tests of Beaver County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slaking minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Max. shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested use
158	22.1	6.9	7	-----	5.0	10	20	02-8	Dk. buff to gray	not much value
165	25.4	6.1	5	234	6.0	4	20	05-6	Lt. buff to gray	face brick, sewer pipe
166	19.3	4.1	15	267	5.1	4	16	4	dark buff	face brick
167	20.4	5.0	14	288	4.4	4	20	1-6	lt. buff to gray	face brick and low grade refractories
168	21.4	-----	7.5	122	4.2	4	15	02-4	dk. buff to black	doubtful
169	23.2	4.4	5	282	7.3	1	13	07-4	lt. red to dk. brown	face brick
170	19.2	4.6	10	286	4.3	4	23	05-8	lt. buff to gray	low grade refractories
171	30.8	9.1	21	765	8.0	02	14	07-1	lt. red to dk. brown	face brick, sewer pipe
172	19.0	1.3	9	101	4.1	10	20	1-10	buff to gray	face brick or low grade refractories
173	24.2	7.5	6	273	4.8	1	13	07-4	red to dk. gray	face brick, drain tile
174	21.7	2.9	7	86	6.4	1	12	05-4	red to black	face brick
175	19.1	3.3	9	171	4.6	6	20	02-8	lt. buff to gray	face brick or low grade refractories
176	23.5	3.2	4.5	151	6.9	4	13	02-1	lt. to dk. red	drain tile
177	18.4	4.8	20	284	2.4	4	27	02-8	lt. buff to gray	face brick or refractories
178	20.4	3.2	14	216	6.5	10	20	1-10	cream to dk. buff	face brick, sewer pipe, refractories
179	22.2	4.0	24	149	8.1	6	16	05-6	dk. buff to brown	face brick
199	21.0	3.2	7	135	7.6	02	8	none	red to black	none
203	20.5	4.1	15	54	4.9	1	10	05-1	red to brown	brick or tile

Table 9
Chemical analyses of Beaver County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
158	9.39	52.95	8.72	.77	24.12	1.61	1.64	-----	-----	.09	.21	.40
165	7.24	60.44	7.26	.97	16.71	-----	-----	-----	-----	-----	-----	-----
166	7.94	62.00	4.35	1.04	18.43	7.46	1.87	-----	-----	.04	.76	.05
168	5.30	62.62	4.37	1.42	17.79	.84	3.14	1.00	1.89	.10	.35	1.02
169	9.03	55.75	7.88	.53	23.73	1.46	1.07	1.25	2.63	.22	.39	.15
170	8.75	55.53	2.54	.73	28.97	.82	.40	.88	.63	Tr.	.38	.59
171	8.74	33.80	7.91	.88	30.30	8.93	3.63	1.13	3.31	.06	.45	.32
172	10.04	61.74	1.55	1.08	17.56	.99	3.99	.26	1.72	.26	.34	.53
173	7.52	57.60	.95	.63	23.24	2.43	1.21	-----	-----	-----	-----	.68
174	9.69	54.82	10.81	.16	18.52	.73	3.36	-----	-----	.02	.61	.42
175	6.97	62.08	4.41	.91	21.45	.74	.70	-----	-----	.07	.12	-----
176	8.15	64.19	6.21	1.36	17.67	.34	1.05	.64	.43	.01	.02	.24
177	7.42	59.24	4.09	1.21	21.44	.75	.78	1.01	2.78	.03	.93	.41
178	4.93	70.64	6.43	.56	14.03	.91	1.34	.53	.27	.08	.02	.18
179	5.88	61.22	1.16	.46	22.17	1.05	1.94	.31	.78	.03	.22	-----

Analyses from earlier reports.

	11.22	46.16	7.21	.74	29.97	2.21	1.52	3.24				
B	6.34	67.78	4.57	.78	16.29	.60	.72	2.00				
C	8.85	61.97	FeO 1.81	1.97	22.94	.44	.52	1.75				
D	7.88	61.75	1.93	1.78	23.66	.45	.35	2.41				
E	8.74	62.89	1.81	1.82	21.49	.38	.56	2.52				
F	7.64	62.26	1.40	1.78	23.89	.47	.30	1.97				
G	7.49	66.61	1.96	2.81	18.39	.49	.54	1.07				
H	8.36	56.67	2.10	1.79	26.56	.26	.27	3.79				
I	9.68	57.67	1.49	2.54	27.52	.38	.12	.61				
J	9.01	60.19	2.09	2.34	24.23	.85	.03	1.66				
K	9.28	61.98	1.39	1.83	23.88	.04	.28	1.21				
L	6.14	68.92	.98	-----	22.38	.19	.17	-----				
M	12.97	57.64	1.22	-----	27.56	.37	.12	.06				

Localities from which samples were obtained.

158. Mahoning clay on road opposite Ambridge.
 165. Middle Kittanning clay near mouth of Crows Run.
 166. Lower Kittanning clay, Pennsylvania Clay Company, Crows Run.
 167. Lower Kittanning clay, Rochester Clay Products Company, Rochester.
 168. Shale below 167, Rochester Clay Products Company, Rochester.
 169. Shale near Haney lumber yard, Rochester.
 170. Lower Kittanning clay, Westmoreland Brick Company, New Brighton.
 171. Terrace clay, W. H. Elverson Company pottery, New Brighton.
 172. Lower Kittanning clay, The Fiske Company, Darlington.
 173. East Palestine clay, Darlington Fireproofing Company, south of Cannelton.
 174. Shale, Beaver Clay Manufacturing Company, New Galilee.
 175. Lower Kittanning clay, Beaver Clay Manufacturing Company, New Galilee.

176. Shale above Vanport limestone, Pittsburgh Clay Products Company, Eastvale.
177. Lower Kittanning clay, McLain Fire Brick Company, Merrill.
178. Lower Kittanning clay, Clydesdale Brick and Stone Company, Frisco.
179. Shale above Vanport limestone, Clydesdale Brick and Stone Company, Frisco.
199. Shale along railroad, 2 miles west of Zelenople.
203. Shale along Rochester road, 2 miles west of Zelenople.
 - A. Terrace clay, Oak Hill Pottery, 1½ miles north of New Brighton on land of Mendenhall and Chamberlain, Pennsylvania Second Geol. Survey, vol. Q, p. 282, 1878.
 - B. Terrace clay, Elverson and Sherwood; New Brighton, *ibid.*
 - C. Lower Kittanning clay, 1st grade, Elverson and Sherwood, New Brighton: *ibid.* p. 180-181.
 - D. Lower Kittanning clay, 2d grade, same locality and reference as above.
 - E. Lower Kittanning clay, 3d grade, same locality and reference.
 - F. Lower Kittanning clay, raw, same locality and reference.
 - G. Lower Kittanning clay, Mendenhall and Chamberlain mines, New Brighton; *ibid.*
 - H. Lower Kittanning clay, Coales mine, New Brighton: *ibid.*
 - I. Lower Kittanning clay, Couch's mine, New Brighton: *ibid.*
 - J. Lower Kittanning clay, Severn's mine, Vanport: *ibid.*
 - K. Lower Kittanning clay, South Barnes, Bridgewater: *ibid.*
 - L. Clay, Bradys Run Fire Brick Company, Mineral Resources of the United States for 1896, 18th Ann. Rept., U. S. Geol. Survey, Pt. 5 (cont.) p. 1155, 1897.
 - M. Upper Freeport clay, Summit Cut, Big Beaver Township, Pennsylvania Second Geol. Survey, vol. Q, p. 46, 1878.

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BUTLER COUNTY

Butler County is, in general, a rolling upland underlain by shales and therefore not rugged. The hills rise to an elevation of 1200 to 1400 feet above sea level and are a part of the Allegheny peneplain of western Pennsylvania. About 100 feet below these levels is a less extensive series of levels which are believed to represent the Worthington peneplain.

The county is drained chiefly to the west by Slippery Rock, Muddy, and Connoquenessing creeks and their branches. A narrow strip of the county along its eastern border drains into Allegheny River through a number of short streams, of which the most important is Buffalo Creek. Allegheny River barely touches the northeast and southeast corners of the county. Most of these streams flow in deep, rugged channels between walls of heavy-bedded sandstones of the lower Conemaugh group.

Only a very narrow belt along the northwest border of the county is within the glaciated area. This area is covered with a bouldery moraine and kame-like hills of glacial material.

The rocks of the county range in age from the Ames limestone of middle Conemaugh age to the Sharon coal of the Pottsville, the entire section amounting to approximately 920 feet of strata. The southern half of the county has lower Conemaugh rocks at the surface with the Allegheny group exposed only in the deeper stream valleys; the northern half of the county is underlain with Allegheny strata and with Pottsville rocks appearing in the valleys.

For the discussion of the clay resources it seems best to divide the county into more or less natural subdivisions.

CLAY RESOURCES**Region South of Connoquenessing Creek**

The southern border of the county is all underlain with lower Conemaugh rocks, with the exception of small areas along branches of Bull Creek near Lardintown, and along Buffalo Creek near Freeport where the Upper Freeport coal and a few feet of strata below it are exposed. The red clays accompanying the Ames limestone on the higher hills are usually fitted for the manufacture of common and face brick although none are now used in the district. The next horizon of interest from the standpoint of clay is the Brush Creek coal, which lies about 140 feet below the Ames limestone. Under this thin coal there is usually found a bed of clay ranging from 6 to 12 feet in thickness. This clay is well exposed in the quarry of the Martin Brick Company at Callery, the section there showing 1 foot of Brush Creek coal overlaid by 20 feet of dark, plant-bearing shales and underlain by 11 feet of blue clay. In 1930 the plant was using a mixture of terrace clays and the blue clay and making light red hollow tile and brick. The blue clay alone makes too light colored a product. Sample 164 of the blue clay indicates that it has fair plasticity and high green strength. It fires to a dark buff to gray color with a firing range of 1000 to 1150° C. and fuses at cone 12. This shows that it is

a clay suitable for making face brick but that it is not a true fire clay. The plant is equipped with dry pans, a Freese brick machine, and uses electric power. This clay is believed to be at the Brush Creek horizon but may be in the Mahoning formation. As in northern Allegheny County, bluish clays of value for face brick manufacture and sometimes even for low grade refractories are apt to occur at these horizons. The Freeport Brick Company at Freeport uses a clay at this same horizon for refractories (see Armstrong County).

At Mars the A. Q. Starr Brick Company manufacturers dark-red common and face brick from a shale which is probably in the Mahoning horizon. Their quarry shows a 15-foot bank of uniform blue shale somewhat weathered and stained with iron. Sample 163, the run of the bank, has good plasticity and low green strength. It burns light or dark red with a burning range of 1000 to 1150° C. and fuses at cone 13. The shale is trammed to the plant by an electric locomotive, molded in a Freese machine, dried in tunnel driers, and burned in 3 round and 2 rectangular coal-fired, down-draft kilns.

Between Mars and Callery much of this shale is exposed and it should be commonly found throughout the southern section. The greater portion of the Mahoning rock is heavy cliff-forming sandstone down to the Upper Freeport coal, for which it usually forms a sandstone roof. The Upper Freeport coal and its accompanying underclay outcrop in this southern area only along the headwater branches of Bull Creek, in one small area on Sarver Run, and along the deep valleys of Little Buffalo and Big Buffalo creeks near Freeport. The coal in these areas ranges from 3 to 4½ feet in thickness and the underlying clay from a very thin white streak to a bed 3 feet thick. The usual thickness of the clay is about 2 feet and it is therefore not of any great value. On the branches of Bull Creek in the vicinity of Lardintown it is from 3 to 4 feet thick. On the line between Clinton and Buffalo townships on Sarver Run it is 3 feet thick. In the vicinity of Monroe on Little Buffalo Creek and thence to Freeport the clay under the Upper Freeport coal seems to be only 1 to 1½ feet thick.

Section ½ mile east of Monroe

	Ft. In.
Mahoning sandstone	75
Upper Freeport coal	3
Fire clay	1 6
Limestone	3 6
Sandy shales	40
Lower Freeport coal	0 10
Clay to railroad	3

Near Harbison the section is carried on down to the Upper Kittanning horizon and shows 2 feet of the Upper Kittanning coal underlain with 3 feet of clay and below that, 20 feet of shale. This indicates that in the region of the Buffalo Creeks northwest of Freeport there are thin clays under the Freeport and Upper Kittanning coals. They have not been tested and on account of their thinness are probably not of any value.

Eastern Part of the County

This part of the county is drained by Rough Run, Little Buffalo Run and its many branches, Little Beaver Run, and Bear Creek, the drainage all going into Allegheny River,

Near the Armstrong County line Rough Run and Little Buffalo Run expose the upper sandstones of the Pottsville series. Above these exposures these valleys are in the Allegheny group, and the hilly region between the valleys is underlain by lower Conemaugh strata. In the vicinity of West Winfield the Pottsville sandstones are exposed and above these both the Clarion clay and the Lower Kittanning clay, each under its respective coal.

The Pennsylvania Clay Products Company at West Winfield manufactures sewer pipe from the Clarion clay, which varies from 6 to 18 feet thick in their mine. This clay (sample 196) has fair plasticity and high green strength. It burns to light buff with a firing range of 1100 to 1250° C. and fuses at cone 29. This indicates that it could be used for refractories as well as for sewer pipe. Fifteen to 20 feet above the Clarion coal lies the Vanport limestone, here 20 feet thick. About 20 feet above it is the Lower Kittanning coal and its underclay. This clay ranges from 6 to 11 feet thick and has been used in the past for the manufacture of fire-proofing. The Clarion clay is accessible along Rough Run for perhaps 2 miles and the Lower Kittanning clay for 4 miles. Farther up the run the higher coals of the Allegheny group are present and no doubt carry some clays beneath them but these are not believed to be of as much value as the clays already mentioned.

Along Little Buffalo Run the Vanport limestone passes under the surface at the Armstrong County line so that no Clarion clay is exposed. The Lower Kittanning clay should have an outcrop of about a mile near the county line and the higher coals and clays should be found farther up the valley to a point about 2 miles west of Fenelton where the stream and railroad rise above the Upper Freeport coal horizon. No information is at hand regarding the thickness or quality of the clays in this valley but they have never been exploited and probably are rather thin. South of Chicora the thickness of the clay beneath the Upper Freeport coal is reported to be 8 to 10 feet and it is said to be largely a flint clay. North from Chicora, beyond a divide underlain by lower Conemaugh strata, is the valley of Little Beaver Run; around Karns in this valley the Upper Freeport coal is present. From Parkers Landing north the Allegheny strata occupy the uplands and the upper portions of the streams. No valuable beds of clay are known but it is likely that at least the Lower Kittanning and the Clarion beds are of value as they are to the east in Armstrong County. Three miles north of Bruin, the highway crosses North Branch and various clays and shales are exposed. These are either of lower Allegheny or of Mereer age. The section along the road south of the stream shows:

Section 3 miles north of Bruin

	Feet
Sandstone	25
Coal and clay blossom	3
Sandstone	6
Brown shale	3
Black shale	6
Sandy buff shale	3
Concealed	10
Brown flinty shale	5
Sandstone and concealed	5-10

Section north side of stream, 3 miles north of Bruin

	Feet	Inches
Sandstones	0	
Shale at road pit (No. 382)	10	
Shaly micaceous sandstone	8	
Thin dark shale	3	
Coal	0	10
Gray shaly clay (No. 381)	6	
Sandy clay and shale	10	
Light gray sandy clay	2	
Shaly sandstone	5	
Concealed	5	

The shale in the pit near the top of the section (No. 382) has good plasticity and a low green strength. It burns to a salmon to dark brown color with a firing range from cone 02 to 6. It seems suited to the manufacture of red brick or tile. The clay below the thin coal (No. 381) shows good plasticity and a low green strength. It fires to a cream to gray color with a firing range of from cone 02 to 6. It could be used for the manufacture of face brick or tile. It fuses at cone 27 and is therefore only a low grade fire clay. In the lower portions of Bear Creek and thence north along the slopes which lead down to Allegheny River, the Pottsville series and some of the underlying Mississippian strata are exposed. The Pottsville rocks consist of heavy-bedded sandstones with only thin layers of shale and thin coal beds. No shale of value was noted and no fire clay. Below the Pottsville 300 feet of the Burgoon formation is present. This consists of sandstone layers interlaminated with greenish shale. The sections seems to include no clay.

Central Part of the County

The peneplain of the central part of the county slopes from 1400 feet above sea level on the north to 1240 feet on the south. It is practically all underlain by strata of lower Conemaugh age, including the Mahoning sandstone at the base. The drainage of the region is chiefly through Muddy Creek, which flows west across the northern part of the Butler quadrangle, and Connoquenessing Creek which heads in the vicinity of Butler and flows southwest. Among its branches are Thorn Creek, Coal Run, Karns Branch, and Newmans Branch. These streams expose the Allegheny strata down to the Middle Kittanning coal horizon while the upper cliffs are often made up of the Mahoning sandstone. There are thus along the railroads which follow these valleys around Butler, extensive shale exposures and an occasional clay bed accompanying the Freeport or the Kittanning coals. The shales are mostly dark colored and iron stained. A typical example of this type of material is the shale bank in the eastern part of the city of Butler at the foot of the hill leading in from the Pittsburgh pike. This shale (No. 202) has good plasticity and low green strength. It fires red or brown with a firing range of 1050 to 1150° C. and fuses at cone 8. It is suitable for the manufacture of building brick and tile. About 15 feet of it are exposed and it is underlain with a thin coal which may be the Lower Freeport. Large amounts of this type of material are to be seen in all the valleys around Butler. Near Oneida Station 2 miles northeast of Butler good shales are exposed along the road. A sample (No. 390) of shale

and clay from the roadside just north of Oneida Station shows good plasticity and a fair green strength. It fires to a buff to dark gray color and has a firing range from cone 1 to 8. It is suitable for face brick manufacture and is in an excellent location with respect to the railroad. Along Connoquenessing and its tributaries southwest of Butler the Upper Freeport coal is about 50 to 75 feet above stream level and all exposures are of these shales; there is a possibility that under either the Upper or Lower Freeport coal a fire clay might be found. These clays are thin and not known to be of value.

In the northern part of the Butler quadrangle in the valleys of Muddy Run and Big Run the Upper Freeport and Upper Kittanning coals are mined and clay of a semi-refractory nature can be obtained as a by-product. Such clay is frequently ground and used in blast furnace cements. This is the practice at the Nealy mine on Muddy Run and at the Misner mine at Claytonia. At Isle in the mine of the Keystone Collieries Company such a clay occurs below the Upper Kittanning coal to a thickness of 3 to 5 feet. Tests made on this clay (sample 201) show that it has fair plasticity, low green strength, and that it burns to light or dark gray with a firing range of 1050 to 1150° C. It fuses at cone 16. This indicates that it could be used for low heat duty refractories. Much of this material is apparently going to waste in the mines of this district and attention should be given to its utilization.

Western Part of the County

This includes the Isle and Porterville portion of the Muddy Creek valley, the highland on which lie Prospect and Portersville, and the valley of the Connoquenessing including Evans City, Harmony, and Zelienople. Along the Connoquenessing valley we find that the Upper Freeport coal lies about 50 feet above the stream at the mouth of Glade Creek and is underlain by a 2-foot bed of clay. Downstream the lower strata appear and at the mouth of Breakneck Creek the Upper Kittanning coal is at stream level with a 3-foot bed of clay beneath it. At Evans City the Upper Freeport coal is exposed. At Zelienople the Upper Kittanning coal is near creek level. In West Zelienople this bed is seen in many cuts with a thin clay below and dark nodular shales above it. The clay seems to be of no value and the shales are similar to sample 199 of Beaver County which is of little value. In fact in the Evans City-Harmony-Zelienople area no clay or shale of much importance was seen.

The clays on Muddy Creek are below the Upper Kittanning coal, as at Isle, already discussed, and the possible occurrence of the Lower Kittanning clay between Barber and Paynes. Here the Vanport limestone is exposed and the Lower Kittanning coal and its valuable underclay should lie above this limestone. It is quite likely that in this area will be found the most valuable clay of the county.

Northern Part of the County

This is an upland of Allegheny rocks drained by Slippery Rock Creek and in the northwest by Wolf Creek. Slippery Rock Creek near its headwaters flows upon lower Allegheny strata and the Brookville coal is the chief coal mined. This is mined at Annandale, Deegan, Ferris, Hilliards, Argentine, and other localities. The Lower and

Middle Kittanning coals are also mined at Clatonia, Sherwin, and Mercer Road. These coals have underclays which at Clatonia and elsewhere have been ground for fire clay cements. Probably the best clay in the district will be the Lower Kittanning which lies a few feet above the prominent outcrop of the Vanport limestone. Little is known about the thickness or quality of the clays of this portion of the county.

In the northwestern part of the county Slippery Rock Creek flows on Pottsville rocks and the Vanport limestone outcrops on the banks not far above the stream. This would place the Brookville coal and clay near stream level and the Lower Kittanning clay in accessible position on the slopes. However, glacial gravels obscure much of this material along the valleys and little is known about these beds. Near the county line and in Lawrence County shales are exposed which are described under sample 220. These are probably above the Vanport limestone. In the vicinity of Harrisville and Slippery Rock small coal mines are operating on the Middle Kittanning coal and this coal has a thin clay beneath it, perhaps 2 to 3 feet thick. West of Forestville (Harrisville Sta.) on the railroad this coal and its weathered clay are exposed with 20 feet of dark, plant-bearing shales below. These shales might be used alone or in mixtures with the clay or soil above. The shale, tested as sample 225, showed good plasticity, low green strength, and burned red with a firing range of 950 to 1100° C. It could be used in the manufacture of common brick and drain tile. This northwest section of the county lies within the glaciated area, the Wisconsin terminal moraine passing east of Slippery Rock and west of Harrisville. The deposits, however, seem to be chiefly sorted sands and gravels of the outwash, and little clay was seen. It is unlikely that glacial clays of any great value for making brick exist in the area.

Summary

The clay and shale resources of Butler County are confined to possible clays and shales of the lower Conemaugh group on the higher lands of the southern half of the county; to the thin fire clays which accompany the Allegheny coals along the main streams of the county; and to the clays which accompany the same coals in the higher lands in the northern part of the county. The only development at present is that at Mars and Callery in the southwest and that at West Winfield in the southeast. The Clarion and Lower Kittanning clays seem to offer the best clays for future development.

Localities from which samples were obtained

163. Shales from A. Q. Starr Co. brick yard quarry, Mars.
164. Clay from Martin Brick Co. quarry, Callery.
196. Clarion clay from mine of Pennsylvania Clay Products Co., West Winfield.
201. Upper Kittanning clay from mine of Keystone Collieries Co., Isle.
202. Shale from cliff at east end of city of Butler.
225. Shale along railroad west of Forestville or Harrisville Station.
381. Clay along road 3 miles north of Bruin near the North Branch.
382. Shale along road 3 miles north of Bruin near the North Branch.
390. Clay and shale along road just north of Oneida.

Table 10
Physical tests of Butler County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slacking minutes	Modules of rupture lbs. per sq. in.	Max. linear burning shrinkage	Max. shrinkage at cone	Fusion point cone	Best burning range cone	Firing color	Suggested uses
163	22.61	3.80	4	142	5.67	1	13	07-1	Light to dark red	Face brick
164	22.5	4.83	7	349	4.79	1	12	07-1	Dark buff to gray	Face brick
196	19.5	4.9	15	124	6.3	1	29	02-6	Light buff to gray	Refractories
201	16.9	3.8	12	86	3.7	02	16	05-1	Light to dark gray	Low grade refractories
202	21.5	4.5	12	77	8.4	1	8	05-1	Light red to dark brown	Brick or tile
225	20.1	3.8	3.5	122	5.70	02	16	010-02	Red to brown	Drain tile
381	20.4	1.8	3.	117	7.3	11	27	02-6	Cream-gray	Face brick and tile
382	23.2	2.9	5.	113	8.9	8	17	02-6	Salmon-dark brown	Brick and tile
390	24.7	4.7	7.	288	8.3	6	19	1-8	Salmon-dark brown	Face brick

Table 11
Chemical analyses of Butler County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
163	5.93	57.50	1.23	.68	23.44	.73	1.66	2.06	3.53	.25	1.32	.31
164	8.48	54.66	9.87	.96	15.59	2.50	-----	-----	-----	.12	-----	-----
196	5.90	59.10	2.22	.14	26.76	.62	.96	-----	-----	-----	-----	-----
225	7.22	62.80	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

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FAYETTE COUNTY

Fayette County is bounded on the west by Monongahela River, with Greene and Washington counties across the river. On the north it is bounded by Westmoreland County and on the east by Somerset County.

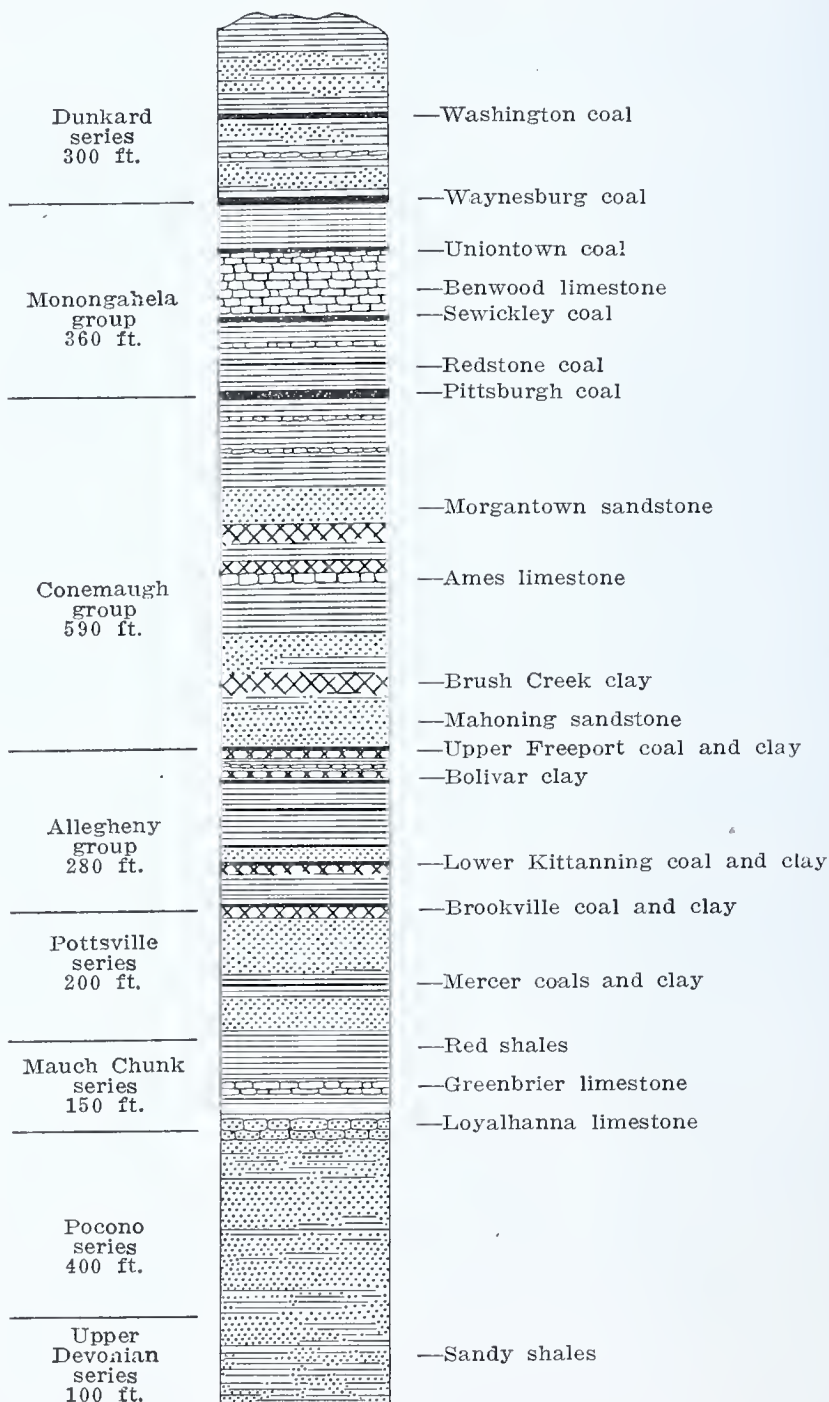


Fig. 11. Section of strata in Fayette County.

The strata exposed in the county range from the Dunkard series down to the upper beds of the Devonian. (see Fig. 11). The upper Devonian and Mississippian strata are exposed only in the two pronounced anticlines, Chestnut Ridge and Laurel Ridge. Outcrops of the Monongahela group and the Dunkard series are found only west of Chestnut Ridge.

The county can be divided into the following areas: (1) a western area of Monongahela and Dunkard rocks bordering Monongahela River; (2) the Fayette anticlinal area along which the Conemaugh group is brought to the surface from Point Marion to Jacobs Creek; (3) the Uniontown coal basin, a syncline of Monongahela and Dunkard strata; (4) Chestnut Ridge, a mountainous anticlinal ridge extending across the county in a direction east of north and lying just east of Uniontown and Connellsville; (5) a synclinal basin between Chestnut and Laurel Ridges and coextensive with Ligonier Valley to the north; (6) Laurel Ridge, a second mountainous anticlinal ridge the crest of which forms part of the eastern boundary of the county; (7) an area of Conemaugh and Allegheny groups in the southeast corner of the county. The western half of the county is industrial and is well served with rail facilities on account of the important coal and coke interests. The Pennsylvania Railroad follows Monongahela River, and Youghiogheny River is followed by the Baltimore & Ohio Railroad and by the Western Maryland Railroad. The intervening territory is crisscrossed by branch lines of these railroads. Chestnut Ridge forms a marked barrier to transportation, being breached in the county only by Youghiogheny River. This gap permits railroads to serve the southeastern part of the county, which is largely given over to agriculture.

CLAY RESOURCES

Monongahela River Area

The eastern or Fayette County side of Monongahela River is followed by the Pennsylvania Railroad. The river has cut deeply into the sedimentary strata and the hills rise abruptly 300 to 400 feet above the stream. The strata exposed near the railroad and river level are those of the upper Conemaugh and lower Monongahela groups, the Pittsburgh coal being generally exposed above river level or dipping slightly below the river.

At Bellevernon the upper Conemaugh strata are to be seen in the lower part of the city and the lower Monongahela strata in the higher parts of the city. The Conemaugh shales were tested from exposures at O'Neil's across the river (see No. 99, Washington County) and are apparently suitable for the manufacture of face brick, sewer pipe, drain tile, and fireproofing. Similar shales should be uncovered in the lower parts of Bellevernon. Back of the city at levels about 200 feet above the river there are deposits of yellowish sand and plastic blue or yellow clay of the Carmichaels formation which were laid down at this high level by a predecessor of Monongahela River. The quality of this type of material can be seen by reference to sample 100 taken at Allenport across the river. This is very plastic clay suitable for making red face brick and tile.

Up the river through Fayette City and Brownsville the Pittsburgh coal is often obscured by terrace gravels and sands and the available shales are those of the overlying Monongahela group. The 1-foot fire

clay parting between the main coal and roof coal in the Pittsburgh bed is persistent in this area and might be used to advantage in the manufacture of buff face brick or refractories. A sample from California, Washington County (No. 101) fused at cone 20 and one from east of West Newton, Westmoreland County (No. 241) fused at cone 32. This parting has been saved during coal mining operations at Manown and other localities and manufactured into refractories of the low heat duty type. Immediately above the Pittsburgh coal and between it and the Redstone coal there are about 40 feet of strata which may be massive sandstone, shaly sandstone, dark shale, or normal gray shale. Sample 102, Washington County, shows that there may be workable shales at this horizon but usually they look unpromising, as for instance, in the vicinity of Brownsville. Opposite California the Monongahela group cliffs carry many layers of limestone, a condition which makes the extraction of the shaly layers difficult. By careful selection, beds of good brick-making shale 6 to 15 feet thick might be obtained. At Grays Landing the Pittsburgh coal is below river level and the exposed rocks are chiefly sandstone and limestone. Just north of Masontown bridge a section along the railroad shows:

Section along railroad north of Masontown bridge

	Feet
Limestone	10
Olive shale	6
Limestone	2
Olive shale	10

The lower shale (No. 96) has fair plasticity, rather low green strength, and fires to dark red with a burning range from cone 07 to cone 1. It is suitable for making common brick and tile. This section is above the Redstone coal. Back from the bridge at Masontown there are good exposures of Carmichaels clay which could be utilized for many purposes.

South of Grays Landing the Pittsburgh coal rises above the river again under the influence of the Fayette anticline. This brings to light more and more of the Conemaugh strata until at the south line of the county some 350 feet of this group is exposed. These Conemaugh beds show the usual alternations of thin limestone, sandstone, shale, and red clay from which, by careful selection, good brick clays may be obtained. Just north of New Geneva a cliff of gray and yellow shale and red clay was sampled as a whole (No. 95). This showed fair plasticity, low green strength, and fired to a uniform dark red body with a firing range of cone 07 to cone 1. It should make good common brick and tile. The elimination of the thin limestone layers is one of the problems in the successful working of the Conemaugh shales.

At the east end of the Cheat River bridge at Point Marion there is an abandoned brick yard which used the olive and buff shales of the upper Conemaugh group for the manufacture of red brick. Under a 20-foot bed of heavy sandstone in this quarry, there is a bed of buff clay 4 feet thick. As do many of the Conemaugh clays, this has the appearance of fire clay but fuses at too low a temperature. This clay (No. 92) has good plasticity and low green strength. It fires to a tan to olive color with a burning range of cone 07 to cone 1 and seems suited to the manufacture of drain tile and fireproofing.

Another Conemaugh shale was taken from the southwestern outskirts of Point Marion. This olive shale (No. 93) shows fair plasticity and high green strength. It burns to a uniform red with a firing range of cone 07 to cone 02. It should make satisfactory red face brick and drain tile.

The Carmichaels clays are prominent on a broad terrace south of New Geneva. They may be sandy or filled with bowlders but are often fine blue, yellow or white clay suitable for the manufacture of brick or stoneware. Their quality can be judged by the tests of similar material in Greene and Washington counties and by sample 94 which was taken from a pit half a mile south of New Geneva. This is a brown, finely-laminated clay now used in foundry work. As is usual with the Carmichaels clay it shows high plasticity and green strength. It fires to a tan, with a range of cone 07 to cone 4. This does not seem to be as good as other samples of the Carmichaels clay, being somewhat more sandy, but other diggings in the area yield a better grade of material.

The terrace clays of New Geneva and Greensboro (across the river) were once extensively used in the manufacture of blue stoneware, jugs, crocks, roofing tile, etc. The industry began in 1857 with the establishment of a pottery at New Geneva using a terrace clay 6 to 8 feet thick. In 1857 a pottery was built at Greensboro and in 1866 another was established. These used clay from New Geneva and from pits 2 miles west of Greensboro. In 1896 a pottery was erected one mile north of Point Marion on the east bank of Monongahela River. This used terrace clay obtained one mile east of the plant. All these plants have long been abandoned but their history is interesting as an indication of the many uses to which these clays may be put. The ware was usually salt glazed on the outside and glazed inside with Albany, N. Y. slip clay.

Area Between Monongahela River and Uniontown Coal Basin

Eastward from Monongahela River lies a high, hilly area in which the surface rocks are those of the Monongahela group overlain in the higher hills by 100 to 200 feet of the Dunkard series. This is an area given over to mining the Pittsburgh coal in the Lambert syncline. Brick shales occur throughout the area but are not used and are not prominent. There are no high grade clays within the area. The Pittsburgh coal crops out along the southeast edge of the Lambert syncline in a line extending from Wickhaven southward through Star Junction to Tippecanoc, Footedale and Masontown. East of this line, the Fayette anticline brings up a belt of Conemaugh rocks which present little of interest but no doubt carry many brick shales which might be utilized. Where the larger streams cross this belt of Conemaugh rocks along the Fayette anticline, they have cut down to the level of the Freeport coal and some of its underlying beds. This condition exists on Redstone Creek, near Upper Middleton, on Youghiogheny River just about Layton and on Jacobs Creek. The exposures on Redstone Creek are poor but there seems to be a thin Upper Freeport coal underlain by 50 feet of sandy shale. No fire clays of value are known in the Allegheny strata at that locality. The Allegheny group as exposed in the Youghiogheny gap is discussed in connection with the Youghiogheny Valley. On Jacobs Creek about 3 miles up from its mouth, there are exposures of the Upper Freeport coal and

of some of the strata immediately below it. The Bolivar fire clay bed was formerly worked at this point but has long been abandoned. Below the Freeport coal along Chestnut Ridge this bed of fire clay is of great value and it is well to keep the Jacobs Creek exposure in mind as a possible area for prospecting.

Uniontown Basin

East of the Fayette anticline, the Pittsburgh coal underlies a distinct synclinal basin which includes Smithfield, Uniontown and Connellsville. This is an intensely active coal and coke region and little attention has been given to the development of the shales. Above the Pittsburgh coal the rocks generally are sandstone with limestone higher in the section. Good olive shale was seen at Smithfield but in general such shales are rare in the district.

North from Connellsville, Conemaugh shales are exposed and half a mile south of Moyer a section shows a 3-foot bed of clay beneath a thin coal. This is in the Conemaugh group and may possibly be the Wellersburg clay. A test of this clay (No. 97) shows fair plasticity, low green strength, and a burned color light buff. It has a burning range of cone 07 to cone 1 and fuses at cone 13. It does not seem to have much value.

At Moyer, the Jos. Soisson Fire Brick Company operates a plant which makes fire brick from clays mined on the mountain to the east. In the past, however, the plant made red brick from the Conemaugh shales.

Section of Soisson Brick Company quarry at Moyer

	Feet
Buff shale (No. 98)	20
Sandstone	6
Shale	2
Limestone	2
Dark coaly shale	3
Limestone	3
Gray crumbly shale	4
Sandstone and shale	10
Red beds with limy nodules	4
Green sandy shale	2
Limestone	1

The upper 20 feet of shale (No. 98) shows fair plasticity and low green strength. The shale fires to dark red with a firing range of cone 07 to cone 1. It fuses at cone 11. It seems suitable for making red face brick and drain tile.

Youghiogeny River Valley

Youghiogeny River enters the county at the southeast corner and takes a northwesterly course across it. Deep gaps through Laurel and Chestnut Ridges and a minor gap through the Fayette anticline afford an easy passage for the river and railroads. The valley is thus the major transportation route across the county.

The rocks exposed in the Youghiogeny Valley above the mouth of Jacobs Creek and Whitsett, are of upper Conemaugh age. The Pittsburgh coal and Monongahela strata cap the hills. The coal bed carries the usual parting between the main coal and the roof division. Above the Pittsburgh coal are sandy shales of little value and above

them is the Redstone coal. South from Whitsett the strata rise rapidly toward the axis of the Fayette anticline. Thence to Fuller the exposed strata belong to the upper half of the Conemaugh group and consist of thin limestones, massive sandstones, and a few shale beds of lesser importance. At Fuller the Ames limestone is at track level and the Wellersburg clays and red beds, which are usually good brick clays, should lie 50 to 100 feet above the tracks. Thence to Layton the northwesterly dip is pronounced and lower and lower beds of the Conemaugh are exposed. Opposite Layton and one mile south of Fuller the following section is seen:

Section opposite Layton

	Feet
Sandstone	5
Clay	5
Sandstone	20
Nodular clay	10
Sandstone to railroad	15
Concealed to river	20

A railroad tunnel passes through the bed of nodular clay and in the Brownsville-Connellsville folio the upper 3½ feet of this clay is termed flint clay. From present exposures it does not seem to be worthy of the term. This clay is apparently about 115 to 130 feet above the Freeport coal and would therefore be near the Brush Creek horizon.

At Layton, on the east bank of the river, the Layton Fire Clay Company mines this clay and uses it in the manufacture of fire clay products. South from Layton along the river, the Upper Freeport coal appears, and in turn the whole Allegheny group. The coals are thin and are not usually accompanied by fire clays of any importance. At one time the Lower Kittanning clay was mined 1½ miles south of Layton and was said to be 12 feet thick. At present only thin coals and clays, seemingly of no value, are exposed along the railroad. In the four mile stretch south from Layton the Pottsville sandstones appear above rail level in the axis of the Fayette anticline. These are extensively mined for the manufacture of silica brick. Near Darnley the Upper Freeport coal descends to river level again on the eastern flank of the anticline, and thence to Dickerson Run all exposures are in the Conemaugh group, with shales available for making brick. The Pittsburgh coal comes rapidly down to the river and reaches railroad level near Adelaide. It remains near rail level to Broadford so that in this stretch the available shales would be those of the upper Conemaugh and lower Monongahela strata. East of Broadford the coal goes below river level and shales of the Monongahela group are present. No use is made of shales between Layton and Connellsville but common brick, face brick, and drain tile could be manufactured between Adelaide and Connellsville from many of the shales.

South from Connellsville for 2 miles outcrops along the river are of the lower Conemaugh group. The most important clay noted in these exposures is between the Brush Creek and Mahoning horizons, possibly the same clay as seen at Layton. On the Baltimore & Ohio Railroad in South Connellsville a clay at this horizon worked by the Jos. Soisson Company consists of 7 feet of plastic clay underlain by 4 feet of harder, semi-flint clay. The plastic clay (No. 27) fuses at

cone 16 and is suitable for building brick, low heat duty refractories, and as a bond with other refractory clays. No. 28, the semi-flint clay, fuses at cone 29 and is classed as a No. 2 flint fire clay. It is used in the manufacture of brick, coke oven brick, and low-heat-duty refractories.

Two miles south of Connellsville on the other side of the river along the Western Maryland Railroad a 3-foot clay bed is present within the Mahoning sandstone horizon. It is classed by Shaw as a No. 3 fire clay having excellent burning properties and satisfactory for refractory manufacture.

On up the valley and just south of Gibson the Allegheny group rises toward the Chestnut Ridge anticline. No good clays were noted in the exposures. In near by localities the Bolivar clay underlying the Upper Freeport coal is of importance but here apparently it is absent or inconspicuous. Farther up the valley, the Pottsville, Mauch Chunk, Loyallhanna, Pocono, and upper Devonian rocks are exposed in regular order. The crest of the anticline is $1\frac{1}{4}$ miles west of the mouth of Indian Creek. Nothing of interest to the clay worker is seen in this section except the Mauch Chunk red shales which might be used in making brick. Most of the exposed rocks are coarse, heavy-bedded sandstone, shaly sandstone, or sandy or dark shale.

This condition continues several miles up the river to Ohiopyle. Here the stream flows over upper layers of Pottsville sandstone, and the overlying strata of lower Allegheny age are within accessible distance in the valley sides.

Section at Ohiopyle

	Feet
Sandstone	20
Clay	5
Coal	3
Clay	2½
Coal	1
Clay	8
Shale	7
Sandstone and concealed	55
Coal (Brookville)	4
Clay	10

Higher in the section the Bolivar clay has been reported as being 8 feet thick but carrying many iron carbonate concretions. Little recent work has been done in the region and little is known of these various clays. Ohiopyle seems to present the best possibilities between Connellsville and the southeastern corner of the county.

Immediately above Ohiopyle the river cuts through Laurel Ridge and again we find heavy sandstone and shaly sandstone prevailing. In the center of the anticline, 5 miles above Ohiopyle, some of the Devonian shales are more argillaceous and might be used for brick manufacture. One mile below Confluence the upper Allegheny rocks are seen with exposures of the Upper Freeport coal. No important clays were noted here although the Bolivar horizon might yield clay in this area. South of Confluence to the Maryland line the river flows in the lower part of the Conemaugh strata with much Mahoning sandstone exposed. No good clays are known in this area but it is well to remember that between the Brush Creek coal and the Upper Freeport coal excellent clay may occur and that a few feet below the Upper Freeport coal is the horizon of the Bolivar clay.

Chestnut Ridge

Chestnut Ridge is a great wooded ridge made up largely of the hard, massive sandstones of the Pottsville and the Pocono series. These rocks are arched up into a great anticline whose crest is approximately the crest of the ridge. The strata dip steeply away from this crest toward the northwest and the southeast. The greater part of the rocks of the ridge are of no interest to the clay-worker as they are too sandy. However, on the flanks of the ridge the Allegheny group is exposed and carries very valuable clays. Red Mauch Chunk shales, between the Pottsville and Loyalhanna strata, are also of some interest as they are often suitable for brick making.

The development of fire clays on the northwest flank of the ridge has been very active because of the industrial importance of the adjoining coal and coke area. Coke making has created a demand for coke-oven refractories and the iron and steel industry has brought a demand for many types of fire brick. The most important clays lie just above the Upper Freeport coal horizon in the Brush Creek-Mahoning strata or below the Freeport coal in the Bolivar horizon. These outcrop 1 to 2 miles up on the side of the ridge.

East of Moyer or northeast of Connellsville in the vicinity of Heminger Mills the Jos. Soisson Fire Brick Company works a clay which, according to Bulletin M 10, is above the Freeport coal. This clay (No. 26) is made up of 2 feet of soft clay underlain by 9 feet of flint clay. It fuses at cone 30 and is classed by Shaw as a No. 2 fire clay. Folio 94 describes the clay in the vicinity of Heminger Mills used in the Moyer plant as being under the Upper Freeport coal, and gives a section showing that the bed of clay 10 to 15 feet thick is separated from the coal by 3 to 4 feet of shale. The folio states that at the surface this clay is apt to show well defined iron nodules but beneath the surface the iron is widely disseminated and makes the clay unusable. Whether these two clays are one and the same is uncertain.

South along the ridge similar clay is mined in South Connellsville by the Jos. Soisson Company a short distance north and half a mile east of the end of the trolley line, near the base of the ridge, according to Shaw. The clay (No. 29) underlies the Upper Freeport coal and consists of 10 feet of plastic clay. It fuses at cone 32 and is a No. 1 fire clay. It is mined with the coal and is manufactured into coke-oven brick, building brick, and refractories. Shaw also in Bulletin M 10 describes samples 27, 28, and 30 which lie along the Youghiogheny River in South Connellsville. These are above the Freeport coal and are excellent clays (see discussion of Youghiogheny Valley clays).

Seven miles south along the ridge near Mt. Braddock, the Eureka Fire Brick Company mines a flint clay, sampled by Shaw as No. 31. This clay is below the Brush Creek coal and is 6 feet thick. It is a No. 2 clay with good burning properties and fuses at cone 29. Another sample of this clay (No. 32) showing 4 feet of flint and plastic clay fused at cone 26½ and is classed as a No. 3 clay with good burning properties.

Still farther south, and east of Fairchance, the Fayette Fire Brick Company mines plastic clay (No. 33) said to be under the Sharon coal in the Pottsville group. This is a 10-foot bed and is used for face brick, coke-oven brick, and fire brick. It has excellent burning prop-

erties, uniform shrinkage and porosity rates, and fuses at cone 18. This may be wrongly correlated and may be from the same bed as the others mentioned.

Hopkins and also Report KKK of the Second Geological Survey mention a glass pot clay mined by Mr. Emme at White Horse (also known as White House or Wymp's Gap). Mr. Emme shipped this clay from Outcrop Station on the Baltimore & Ohio Railroad, 2½ miles from the mine. This clay lies under the Freeport coal and is thus of the same horizon as many now being worked. It is evident that there are high grade fire clays all along the ridge and that the principal horizons seem to be either 50 to 100 feet above the Upper Freeport coal or a few feet below that coal. Many operations have been abandoned, however, on account of the high iron content of the clay.

Higher in the ridge the Mauch Chunk red shale is the only promising bed. A sample of this (No. 227) was collected along the National Highway on the west slope of Chestnut Ridge, where about 35 feet of the shale is exposed. This material has good plasticity and green strength, and burns red with a firing range of cone 07 to cone 4. It should make face brick and hollow tile. Large quantities of this shale are available along the ridge but little of it is accessible to a railroad except in the Youghiogeny Gap.

Ligonier Valley

Little is known of the clays in the valley between Chestnut and Laurel ridges. It is a synclinal valley of Conemaugh and Allegheny strata. On account of its somewhat isolated situation and the absence of the Pittsburgh coal this valley supports little industry except agriculture and there has been little incentive to develop clays and shales. The Allegheny group no doubt carries fire clays in this area, especially up against the flanks of the two ridges, and these clays may be developed along Youghiogeny River near Ohiopyle. The Conemaugh group doubtless is largely brick shales, perhaps with better clays in the Brush Creek and Mahoning horizons.

Laurel Ridge

Laurel Ridge or Laurel Hill is an anticlinal ridge similar to Chestnut Ridge and extending parallel to it on the eastern border of the county. As in Chestnut Ridge its main rocks are massive sandstones and the only shales of value are the Mauch Chunk shales and certain beds in the Devonian. Little can be done with these except in the Youghiogeny Valley where they might be utilized in making brick.

Southeastern Area

The southeast corner of the county, east of Laurel Ridge, is an area of Allegheny and Conemaugh rocks similar to those of the Ligonier Valley. They are accessible only along Youghiogeny River and its tributaries. For many miles the river flows at about the horizon of the Freeport coal and some of the fire clays above or below this coal may be utilized.

Table 12

Physical tests of Fayette County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slaking minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested use
26	23.58	5.1	1½	-----	4.0	8	30	-----	-----	No. 2 fire clay
27	17.46	4.5	5	-----	4.3	8	16	-----	-----	Face brick and low grade refractories
28	19.73	3.5	3	-----	3.4	13	29	-----	-----	No. 2 fire clay
29	21.49	7.0	6½	-----	8.0	8	32	-----	-----	No. 1 fire brick
30	18.92	4.1	6½	-----	6.4	8	26	-----	-----	No. 3 fire clay
31	21.48	4.3	2½	-----	5.4	6	29	-----	-----	No. 2 fire clay
32	21.42	5.1	6	-----	5.0	8	26½	-----	-----	No. 3 fire clay
33	20.33	4.2	26	-----	8.0	10	18	-----	-----	Face, paving and coke oven brick
92	27.6	9.5	5	243	8.6	1-4	13	07-1	Tan to olive brown	Drain tile, fire proofing
93	25.4	9.5	3	306	7.8	02	11	07-02	Uniform red	Face brick, drain tile
94	32.2	7.6	9	351	9.6	1	17	07-4	Tan	Doubtful.
95	25.8	7.1	4	160	7.2	1	7	07-1	Light to dark red	Common brick
96	26.1	4.5	5	140	6.1	1	7	07-1	Uniform dark red	Common brick, drain tile
97	22.6	5.1	3	162	5.5	1	13	07-1	Light buff	No value
98	26.0	5.5	5	145	9.1	1	11	07-1	Salmon to dark red	Face brick, drain tile
227	17.8	3.7	8	225	6.0	4	12	07-4	Red to brown	Face brick, hollow tile

Table 13

Chemical analyses of Fayette County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃	
26	3.91	62.98	7.10	1.09	17.21	1.98	1.49	.83	2.05	.15	.21	.40	-----
27	6.81	58.33	5.74	.72	24.14	2.02	1.09	.59	.92	.03	.04	.18	-----
29	9.92	53.50	1.19	.07	29.45	1.42	.25	1.84	1.52	.27	.006	.50	-----
31	12.50	52.80	.50	32.70	.18	.22	-----	-----	-----	-----	-----	-----	-----
33	5.95	64.18	4.43	1.09	19.72	.89	-----	-----	-----	-----	-----	-----	-----
92	7.65	58.02	4.03	.37	27.67	1.22	1.23	-----	-----	-----	-----	-----	-----
93	7.43	53.85	8.14	1.38	19.63	1.63	2.67	1.95	1.54	.48	.36	.41	-----
94	5.25	62.13	4.33	1.31	21.16	1.78	3.17	.84	.49	.07	.04	.24	-----
95	12.85	49.54	10.48	.74	17.64	-----	6.38	.17	.10	.001	-----	-----	-----
96	9.65	49.81	5.71	.24	23.48	1.65	2.37	3.88	1.89	.04	.01	.28	-----
97	6.40	63.29	6.93	1.26	17.64	.57	1.45	2.96	1.54	.04	-----	-----	-----
98	5.80	62.49	6.51	.73	21.67	2.01	1.02	.25	.15	.02	.27	.06	-----
227	5.03	62.64	-----	-----	-----	.85	.71	-----	-----	-----	-----	-----	-----
A	9.29	64.89	.29	-----	24.68	.41	.19	.16	.87	-----	-----	-----	FeO .21
B	11.94	54.23	.21	-----	32.80	-----	-----	-----	-----	-----	-----	-----	-----

Localities from which samples tested were obtained

26. Clay above Upper Freeport coal. Jos. Soisson Fire Brick Company, 4½ miles N. E. of Connellsville in Bullskin Township.
27. Semi-flint clay. Jos. Soisson Fire Brick Company, town of Gibson or South Connellsville on B. & O. R. R. and Youghiogheny River.
28. Flint clay under No. 27.
29. Plastic clay. Jos. Soisson Fire Brick Company, South Connellsville, a short distance north and ½ mile east of end of trolley line.
30. Plastic clay 2 miles SW. of Connellsville on Western Maryland Railroad.
31. Flint clay. Eureka Fire Brick Company, 7 miles SW. of Connellsville on main line of B. & O. R. R.
32. Plastic and flint mixture from No. 31.
33. Plastic clay. Fayette Fire Brick Co., at Fairchance.
92. Clay under sandstone at Point Marion bridge.
93. Shale at SW. edge of Point Marion.
94. Terrace clay ½ mile SE. of New Geneva.
95. Shale on railroad north of New Geneva.
96. Shale on railroad north of Masontown.
97. Clay, 0.6 mile S. of Moyer on road.
98. Upper shales, Soisson brick yard, Moyer.
227. Mauch Chunk shale. West slope of Chestnut Ridge on National Highway.
- A. Glass pot clay. Mrs. Wurm, 1 mile east of Layton. Analysis from Hopkins report, p. 90.
- B. Glass pot clay. Mr. Emme's pit at White House (White Horse) or Wymp's Gap 2½ miles from Outcrop Sta. on B. & O. R. R. Analysis from Hopkins report, p. 98.

Numbers 26 to 33 are analyses taken from Bulletin M 10, Pa. Geol. Survey.

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GREENE COUNTY.

Greene County occupies the southwest corner of the State. It is bordered on the east by the Monongahela River, on the north by Washington County and on the west and south by West Virginia.

Physiographically, the county is a dissected upland on the divide between the Monongahela and Ohio rivers. The highest points on this upland are 1500 to 1600 feet above sea level and are somewhat uniform in altitude. These highlands are chiefly in the central and western parts of the county.

A striking series of levels is shown in a number of rock terraces carved by earlier streams which paralleled the present streams or followed slightly different courses. The rock floors of these terraces are 950 to 980 feet above sea level or about 200 feet above the present streams. They are generally covered by a variable amount of sands, gravels and clays known as Carmichaels formation. These flat areas underlain by the yellowish Carmichaels deposits are prominent topographic features along Tenmile Creek east of Jefferson, along Ruff, Muddy, and Whiteley creeks and Monongahela River.

Greene County is, in general, a rolling country with few rock exposures, as it is largely underlain by shales. It carries a thin residual soil and is devoted chiefly to agriculture. In former days it was an important wool producing region. The dissection of the plateau has been extremely thorough and the country is now broken into a maze or network of deep valleys. Roads, of necessity, wind through these valleys in irregular pattern. The general upland level is about 750 feet above Monongahela River into which the greater part of the county is drained through Tenmile, Muddy, Whiteley and Dunkard creeks. These streams have wide, terrace-bordered valleys in their lower courses and narrow, steep valleys in their upper reaches.

The western part of the county drains west and south through branches of Wheeling and Fish creeks.

The Monongahela Division of the Pennsylvania Railroad follows the west bank of Monongahela River, and a branch line extends up Tenmile Creek to Waynesburg, the county seat. The greater part of of the county is still without rail facilities but this lack has been somewhat offset in the last few years by the construction of excellent highways which connect Wayensburg with Morgantown, W. Va., Washington, Pa., and with the more important villages in the county.

STRATIGRAPHY

The county is underlain by sedimentary rocks of Permian and Pennsylvanian age. These consist of nearly horizontal layers of shale, sandstone, limestone and coal. The oldest and lowest of these beds are exposed in the southeast corner of the county along Monongahela River. The highest or youngest of them occur in the high hills of the western part of the county. From lowest to highest they form an impressive pile of strata 1800 feet thick. They are subdivided as follows:

Permian	{	Greene group, 700 feet thick
		Washington group, 400 feet thick

Pennsylvanian { Monongahela group, 400 feet thick
 { Conemaugh group (upper part),
 300 feet thick

These four groups are subdivided into members, with definite names, as the Pittsburgh coal, Upper Washington limestone, Waynesburg

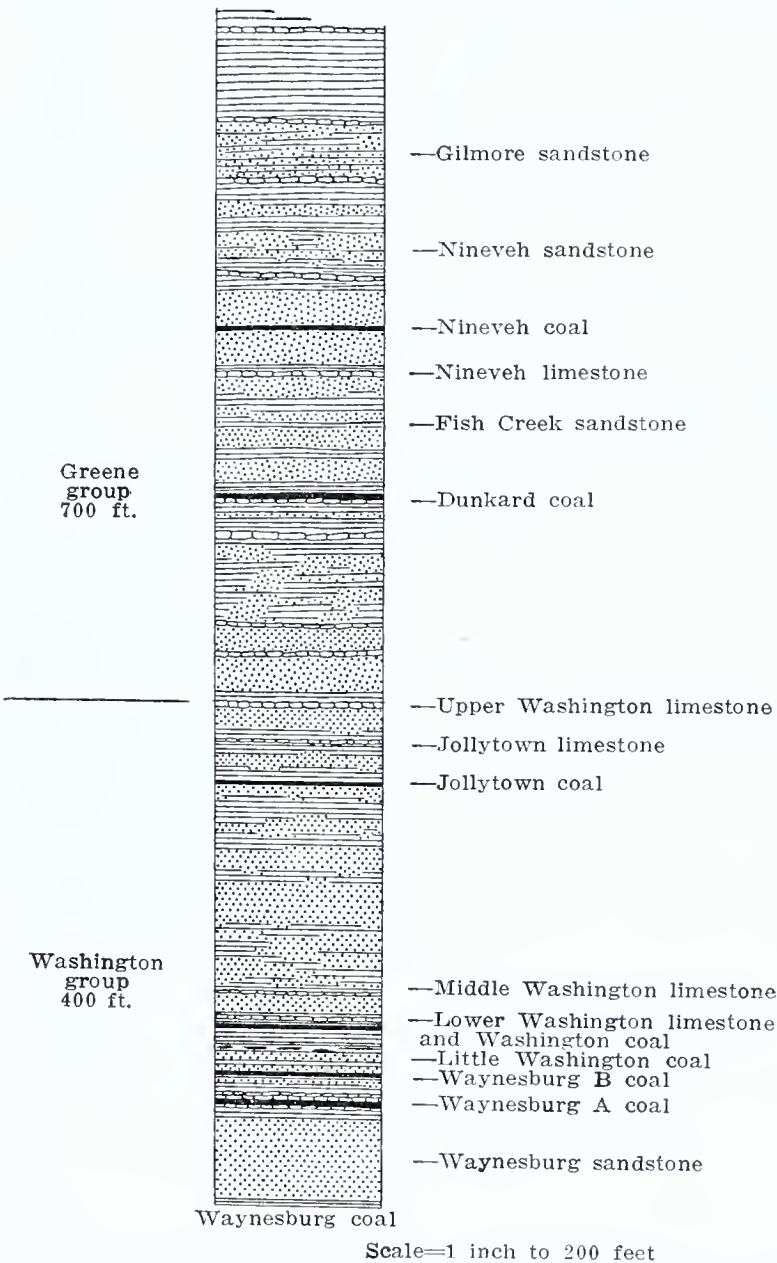


Fig. 12. Section of Permian strata in Greene County.

sandstone. Although the manufacturer of clay products may be interested only in the beds of clay and shale, their position is often determined by reference to some prominent coal bed or other stratum and he should have the whole section in mind. Then, too, a limestone may interfere with quarrying operations, and a coal bed may be of

value to him or a nuisance. In Greene County the sandstones are the most prominent rocks; the thin coals and limestones are usually obscured by soil or crumbling shale.

Greene Group

As seen from the map (Plate 1) this group is the surface rock on the higher hills in the Wheeling Creek drainage area in the western part of the county; occupies a wide belt west of Waynesburg, including the villages of New Freeport, Rutan and Ninevah; and occurs on the higher hills in the central part of the county and on a few knobs in the eastern part. In it are included all strata above the Upper Washington limestone (see Fig. 12), in all some 700 to 800 feet of beds. This group includes two or three coal beds rarely over one foot thick and of no value.

Eight or more limestones are contained in the group; all of these are of the dense, compact type which we recognize as of non-marine origin. These limestones are usually only a foot or two thick and have no value. Coal and limestone beds must be watched for in selecting clay or shale quarry sites for they are detrimental and furnish a problem in separation.

The shales of the Greene formation range from red to light buff in color and from a pure, thin, laminated type to a coarse sandy shale which grades into sandstone. The reddish varieties become more prominent toward the top of the section and are more abundant in the southwestern corner of the county.

Little fire clay is found in connection with the coal beds or elsewhere in the Greene group. Under the Dunkard coal half a mile east of Rutan a bed of clay four feet thick is exposed, underlying an 18-inch bed of cannely shale. A sample of this clay (No. 85) was collected and tested. Although it looks like fire clay the tests show that it fuses at too low a temperature for fire brick manufacture. It would, however, make buff face brick or possibly sewer pipe. Many clays in the county may look like fire clay and some locally may be called fire clay but no one can determine their value without burning tests or chemical analyses. It is well to keep in mind, however, that a plastic clay under a coal bed, even if not a true fire clay, may be of value for face brick or sewer pipe.

The red shales of the Greene group are well exposed at New Freeport. Sample 89 represents a 10-foot bed of shale lying under sandstone at that locality. The tests show that this shale has fair plasticity, high green strength, a firing range of good length, and that it fires to a light red to brown color. It is suitable for the manufacture of face brick, drain tile or fire-proofing. Much of this type of shale can be obtained in Greene County when it is needed.

A buff shale not thinly laminated is common in the hills around Waynesburg, especially to the north. This was not tested but it seems very similar to shale in the Washington formation represented by sample 88, which is of high quality and suitable for buff face brick or sewer pipe.

The Greene group contains many buff and red shales of good quality for manufacturing face and common brick. Some may also be used in making sewer pipe. Thin under clays **might** be used for sewer pipe.

Washington Group

This group consists of 400 feet of strata which underlie the Greene group and overlie the Waynesburg coal bed. The most prominent stratum in the series is the heavy-bedded Waynesburg sandstone which lies at the base. Above this in a distance of 100 feet there are several thin coals and fresh-water limestones of no value. Above these are 200 feet of thin sandstones, olive-colored or buff shales, and a few beds of blue shale. Near the top of the section are the Jollytown coal and limestone and finally the Upper Washington limestone. This is not as prominent as it is around Washington and where absent or obscured, the contact of the Greene and the Washington groups is hard to find. The group is exposed in its entirety in the vicinity of Durbin and in part along the forks of Wheeling Creek in western Greene County. It is exposed on Browns Creek and the South Fork of Tenmile Creek west of Waynesburg. It is also seen along Ruff Run, Smith Creek, and over the greater part of the region east of Waynesburg.

No fire clays of any importance accompany the coal beds in this group. The shales are more prominent in the upper half of the group. They are usually buff, olive, or blue. Red shales are less common than in the Greene group, and dark shales are rare except below the coals.

Sample No. 88 represents the buff shale of the Washington group along the Kirby road 2 miles south of Cummins. This sample was taken at the foot of a hill and is a fair average of the material of the hill. It has good plasticity, a fair green strength, a firing range from 1900 to 1200°C., and fires to a salmon or brown color. It could be used for the manufacture of face brick or sewer pipe.

Another shale of this group (No. 83) was sampled from a roadside cliff at the foot of a high hill three miles north of Spraggs. The sample represents a 10-foot cliff of red, buff, and blue shale. It has good plasticity, a high green strength, fires to a light red to brown with a firing range of 1000 to 1150°C. This seems to be a shale of excellent quality and capable of use in making face brick, paving brick, tile and sewer pipe.

Some of the thin blue slaty shales of the group are of less value and should be avoided. They outcrop along the Smith Creek road for several miles south of Waynesburg. Sample 84 is of this material and the tests show that it has very low green strength, poor firing color, and a very low firing range. Such material is of no value.

The only brick-yard in the county, the plant of the Brick and Stone Company, one mile south of Waynesburg, is using shale of the Washington group. The deposit worked is a steep face of shale and sandstone with the following section:

Section at brick-yard south of Waynesburg

	Feet
Sandstone	10
Red shale	3
Brown shale	10
Blue shale	4
Sandstone	

The shales can be separated and used individually but the usual practice is to mix all three types in their normal amounts. Such a mixture is represented by sample No. 82. This shows fair plasticity

and high green strength. It fires to red or brown with a firing range of 1000 to 1150°C. It is suitable for the manufacture of face brick, floor tile and drain tile.

The shale is trammed from the quarry to the plant, is passed through a Stevenson dry-pan, through a Freese auger machine and cutter. The brick are dried in tunnel driers, burned in round, down-draft kilns fired with coal. The product is a dark red face brick, flashed or clear, and back-up tile.

Similar shale occurs just west of Waynesburg, on the road to Rutan, between Rutan and Holbrook, and between Waynesburg and Sycamore. Some of this is red but most of it a non-sandy olive shale. It is abundant along the old narrow-gauge railroad between Washington and Waynesburg and could readily be worked if use could be made of that road.

Monongahela Group

This group of strata includes the rocks between the Waynesburg coal at the top the Pittsburgh coal at the base, including both coals. The group is about 400 feet thick, and contains the Redstone coal, 50 or 60 feet above the Pittsburgh bed, the Sewickley coal, known also as the Mapletown, 120 to 150 feet above the Pittsburgh, and the Uniontown bed, 275 feet above the Pittsburgh coal.

The Waynesburg coal ranges from 5 to 9 feet thick, usually with a parting of one foot of shale or clay. It is a source of some domestic fuel but is of much less value than the Pittsburgh coal.

The Sewickley coal is of mineable thickness only in Monongahela and Dunkard townships and is mined commercially at several places along the river where it ranges from 4 to 6 feet thick.

The Redstone coal is usually less than 18 inches thick and is often represented only by bituminous shale.

The Uniontown coal is rarely over one foot thick and is often only a dark shale.

The Pittsburgh coal bed is the important coal of the county. It is exposed along Monongahela River and up its tributaries and is developed close to the river. The deeply buried Pittsburgh coal in this county constitutes one of the great reserves of bituminous coal in the State.

The Pittsburgh coal bed is generally divided into a roof division of interlaminated coals and thin shaly layers; a foot of clay called the main parting; and three benches which together constitute the main coal. This main coal is the portion generally worked and ranges from 5 to 8 feet thick. (See Fig 13)

Next to the coals in interest and overshadowing them in thickness are the beds of fresh-water limestone. In places these make one-quarter of the whole Monongahela group and have a total thickness of 100 feet. The individual limestones are: the Uniontown, under the Uniontown coal; the Benwood, between the Uniontown coal and the Sewickley coal; the Fishpot, below the Sewickley coal; and occasionally a thin limestone, the Redstone, beneath the Redstone coal.

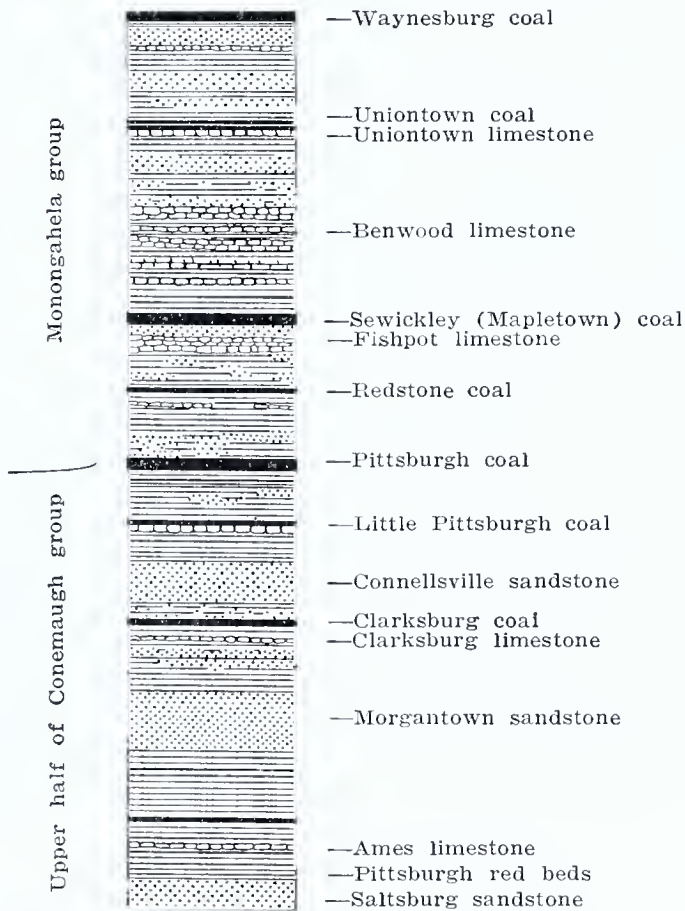
Suitable shales for brick making can be obtained in this group if careful selection is made so as to avoid the inclusion of limestone or coal in the quarry. Sample No. 96 represents the lower 10 feet in the following section along the railroad just north of Masontown bridge.

Section along railroad north of Masontown bridge

	Feet
Gray limestone	10
Olive shale	6
Limestone, weathering brown	2
Olive shale	10

Similar shale sections could no doubt be found on the Greene County side of the river. This shale has fair plasticity, low green strength, fires to a uniform dark red, and has a firing range of 1000 to 1150° C. It should make good common brick.

The shale above the Pittsburgh coal may be found to be of value in



Scale 1 inch=100 feet

Fig. 13. Section of Conemaugh and Monongahela Groups in Greene County.

some parts of the county as it is in other counties, but along Monongahela River it is replaced by coarse, heavy-bedded sandstone.

Fire clays are of little importance in the Monongahela group. The Pittsburgh coal is rarely underlain by any fire clay of value but the parting in the coal bed is often fire clay or refractory shale. It has been used in Washington County for the manufacture of low-duty refractories and its qualities are discussed under that county. Some of the Pittsburgh coal mines in Greene County may sometime save and use this parting clay.

The Waynesburg coal is usually a double bed with a thin shale parting, which, in places, becomes fire clay. Over small areas this fire clay

may thicken into a workable deposit. An old record indicates that one mile south of Arensburg a 5-foot bed of this clay was once disclosed.

The Monongahela group forms an area 4 miles wide in the southeastern part of the county, extending from Monongahela River up Dunkard, Whiteley, Little Whiteley, and Muddy creeks. It also forms a narrow belt of cliffs from Masontown bridge north to Rices Landing and extends up Tenmile Creek almost to Waynesburg. Small exposures of the Waynesburg coal and its underlying shales are also to be seen on Enlow and Dunkard forks of Wheeling Creek in the vicinity of Durbin, and two miles west of Burdette.

Conemaugh Group

The lowest rocks in the county belong to the upper half of the Conemaugh group. They are exposed in the southeast corner of the county on Dunkard Creek and Monongahela River, where they have been brought above stream level by the Fayette anticline, whose crest or axis crosses the river close to the State line. The dip of the Conemaugh strata thus uplifted is toward the northwest, carrying them below the level of Dunkard Creek within a few miles of its mouth and below the level of Monongahela River just south of Grays Landing. Near Point Marion about 300 feet of Conemaugh beds are poorly exposed.

The exposed part of the group extends from the base of the Pittsburgh coal down through 300 feet of rocks, chiefly sandstone and shale, to a horizon probably near the Ames limestone. Normally the group carries some good shales, some crumbly red beds, and occasionally a low grade, crumbly, gray clay which resembles fire clay but is much too limy. The qualities of one of these pseudo-fire clays is shown in sample 92 of Fayette County. These clays may be used in the manufacture of buff brick, drain tile and fire proofing. This sample was obtained at the east end of the Point Marion bridge and similar material no doubt is present on the Greene County side.

Sample 93 is yellow and olive shale from the west end of Point Marion. It shows fair plasticity, high green strength, burns to a uniform red with a firing range of 1000 to 1100° C. It seems to be suitable for making face brick and drain tile. It occurs along the highway leading southwest from Point Marion and is accessible for plant operations.

Sample 95 is of a shale along the railroad north of New Geneva, Fayette County and similar shales must occur on the west side of the river. It is a red-burning shale suitable for making common red brick.

These tests indicate that the shales of the Conemaugh group can be used in red brick manufacture. These shales occur in cliffs on Monongahela River in accessible position, with the Pittsburgh coal just above and available as fuel.

Carmichaels Formation

As mentioned earlier, flat-topped terraces lie along and above Monongahela River and some other streams in the county. These terraces are the sites of former streams and are, therefore, covered by deposits of gravel, sand and clay. The material on the upper terraces is termed

the Carmichaels formation. This material is well displayed along Ten-mile Creek almost to Waynesburg, and forms the flat upon which Jefferson is built. It forms a great flat south of Rices Landing, extending over toward Jacobs Ferry. A good exposure of it extending up Muddy Creek valley, through Carmichaels and out along Little Whiteley valley through Paisley, represents an abandoned loop of the earlier river. A fine terrace of it lies south of Grays Landing, back of Greensboro, and along Dunkard Creek. It is seen up Muddy Creek to Khedive and up Whiteley Creek to Kirby and Cummins.

The thickness of the material ranges from a few feet up to 60 feet. It usually contains gravel or bowlders at the base which are overlain by yellow sand and silt and in some places by mottled yellow and white plastic clays which may be beautifully laminated, as if deposited in ponded portions of a valley. No regularity in section exists because of the variation in direction and velocity of the depositing streams.

The clayey portion of the formation was formerly used for making brick or pottery in many localities in southwestern Pennsylvania. In Waynesburg brick were made from it; at Khedive in 1902 a church was built of brick made from the local clay; in Greensboro, in former years, stoneware and roofing tile were made from it and similar ware was made across the river at New Geneva.

Samples of the Carmichaels clay were tested as follows: Sample 86 was taken at the top of the steep hill leading down to Rices Landing. It shows fair plasticity and green strength and fires to a salmon color with a firing range of 1100 to 1250° C. It seems well fitted for the manufacture of face brick. Sample No. 87 was taken from a cellar excavation 3 miles west of Rices Landing. It also shows fair plasticity and green strength and fires to a salmon color. Its firing range is a trifle greater than in the other sample, ranging from 1000 to 1250° C. It could be used for the manufacture of face brick or sewer pipe.

Carmichaels clay is shown by these tests and those made on samples from other counties, to be a valuable clay having excellent plasticity, a long firing range, and a fusion point around cone 12 to 17. In spite of the irregularity of its deposition it seems that it should be more generally used either in a revival of the stoneware and roofing tile industry, or in the manufacture of sewer pipe and face brick.

Table 14

Physical tests of Greene County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slacking in minutes	Modulus of rupture lbs. per sq. in.	Linear burning shrinkage max.	Max. shrinkage at cone	Fusion point cone	Best burning range cone	Firing color	Suggested uses
82	23.2	5.1	6	366	5.4	1	11	07-1	Red to brown	Face brick, floor tile, drain tile
83	25.0	7.4	5	429	7.7	02	13	07-1	Light red to brown	Face brick, paving brick tile, sewer pipe
84	21.9	3.3	3	80	8.3	4	9	none	Poor	No value
85	25.8	9.0	5	419	7.1	02	10	07-1	Salmon to light brown	Buff face brick, sewer pipe
86	28.0	6.4	8	282	10.8	6	14	02-6	Salmon to dark brown	Buff face brick
87	24.0	6.6	-----	-----	7.0	6	14	07-6	Salmon to gray brown	Gray face brick, sewer pipe
88	27.6	6.1	5	281	10.5	1	12	07-4	Salmon to brown	Gray face brick, sewer pipe
89	25.2	8.4	7	324	7.6	6	13	07-6	Light red to brown	Face brick, drain tile, fire proofing

Table 15

Chemical analyses of Greene County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
82	7.08	55.49	9.07	.06	20.91	2.35	2.11	.86	2.42	.08	.02	.00
83	6.93	57.34	7.65	1.19	22.49	1.60	.34	.89	1.43	.07	.26	.76
84	7.09	55.50	7.81	1.13	21.74	3.63	1.02	.87	.43	.22	.08	.51
85	7.81	56.91	5.31	.73	21.30	4.39	.18	.86	.36	.14	.09	.76
86	4.20	59.98	3.51	.23	23.38	.50	.88	1.11	.87	.07	.01	.08
87	3.47	74.00	7.22	.37	12.21	.33	1.22	-----	-----	.05	.53	.00
88	5.35	56.67	7.69	1.20	24.27	.82	-----	-----	-----	.09	-----	-----
89	7.10	48.21	10.46	1.55	23.40	3.34	2.61	1.32	.76	.09	.87	1.16

Localities from which samples tested were obtained

- 82. Bin sample. The Brick and Stone Company quarry, Waynesburg.
- 83. Road exposure of shales three miles north of Spraggs.
- 84. Road exposure, thin blue shales, 3 miles south of Waynesburg.
- 85. Buff underclay along road half a mile east of Rutan.
- 86. High terrace clay west of Rices Landing.
- 87. High terrace clay 3 miles west of Rices Landing.
- 88. Buff, olive shales on road 2 miles south of Cummins.
- 89. Red shales in village of New Freeport.

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INDIANA COUNTY

Indiana County lies east of Armstrong, south of Jefferson, west of Clearfield and Cambria, and north of Westmoreland County. From the latter it is separated by Conemaugh River. It is a county given over largely to agriculture and in certain areas, to extensive coal mining. Indiana is the county seat and also the largest city.

The topography is that of a rolling plateau whose higher portions rise to heights of 1500 to 2000 feet above sea level; the lowest point on Conemaugh River is about 830 feet above the sea. Conemaugh River, the southern boundary, is the only large river in the county. It flows in an open valley except where it has carved deep gaps in the resistant sandstones through Laurel and Chestnut ridges. These gaps are known respectively as Conemaugh Gap and Packsaddle Gap. The other streams in the county flow in low wide valleys except where they cross Chestnut Ridge or subordinate anticlines. From south to north the principal streams are Black Lick, Two Lick, Little Yellow and Yellow, and Cush creeks. The drainage of the county is chiefly into Conemaugh River to the south, and to Allegheny River to the west. The northeastern townships are drained by Cush Creek and other tributaries into Susquehanna River to the east.

The most prominent feature of the topography is the highland known as Chestnut Ridge. This is a broad hilly belt which rises several hundred feet above the general elevation of the county, its crest being between 1600 and 2000 feet above sea level. It extends from Packsaddle Gap on Conemaugh River to the northeast corner of the county. It is a continuation of the great anticline which forms Chestnut Ridge in Westmoreland and Fayette counties, but in Indiana County the character of the ridge is much less rugged.

The gentle topography has made transportation a comparatively simple problem and railroads penetrate almost every section of the county. The Pennsylvania Railroad follows Conemaugh River and Black Lick Creek and also sends a branch up Two Lick valley to Indiana, the county seat. The Buffalo, Rochester & Pittsburgh Railroad enters the county from the north (from Punxsutawney) and passes through Home to Iselin and Aultman in the southwestern part of the county. The Buffalo & Susquehanna Railroad has a branch from Juneau to Sagamore. The Baltimore & Ohio extends from Creekside through Indiana to Josephine. Branches of the New York Central serve the eastern mining district such as Clymer, Heilwood and Glen Campbell. The main line of the Buffalo, Rochester & Pittsburgh Railroad cuts across the northwestern corner of the county and a branch of the Pennsylvania Railroad across the northeastern corner.

The county has a number of excellent paved highways. The most prominent are the north-south highway from Punxsutawney through Indiana to Blairsville; a portion of the William Penn Highway east from Blairsville, over Chestnut Ridge to Armaugh and beyond; and Route 80 from Saltsburg northeastward through Indiana, Clymer, and Arcadia.

STRATIGRAPHY

With the exception of one small igneous dike in a coal mine at Dixonville, the strata of the county are all sedimentary and are not greatly disturbed. The generalized section is shown in Figure 14. This shows that the entire column of exposed rocks in the county amounts to about 2175 feet, and includes 115 feet of Upper Devonian strata, 870 feet of

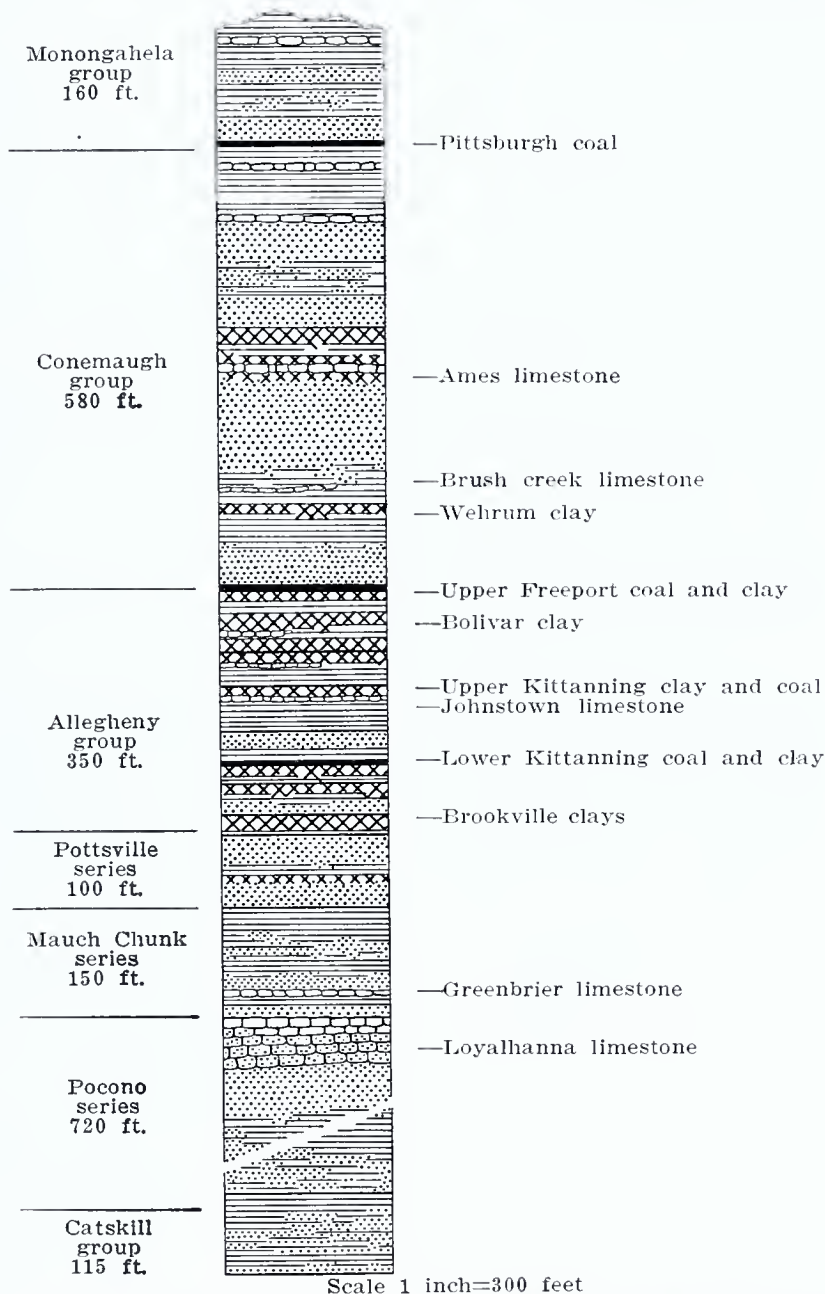


Fig. 14. General section of strata of Indiana County.

Mississippian or Lower Carboniferous rocks, and 1190 feet of Pennsylvania or Upper Carboniferous beds.

The Devonian strata are exposed only in Conemaugh and Paeksaddle gaps of Conemaugh River. They consist of red shales, and gray and greenish sandy shales, the softer of which might be of value in making brick (see sample 358, Cambria Co.).

The Mississippian strata shown in Figure 14 are made up of sandy Pocono sandstone, the sandy Loyalhanna limestone, and the Mauch Chunk red beds. The red shales are the only portion of interest to the clay worker. As seen from tests made on similar shale from other counties they may be used in the manufacture of common and face brick. The Mississippian beds are exposed in the gaps of Conemaugh River and also in the gap of Black Lick Creek east of Josephine.

The Pottsville strata are exposed in the gaps of the Conemaugh River and in smaller areas along other streams which cut across the Chestnut Ridge anticline. Of these, the principal ones are areas on Yellow and Little Yellow creeks, on Black, Two Lick, and Little Mahoning creeks and Bear Run. The Pottsville series is primarily made up of coarse sandstones with only minor amounts of shale, clay, and coal. At none of the exposures in the county has any clay or shale of value been seen. However, in other counties, as Clearfield, valuable flint clays have been found in the Pottsville series and there is a possibility that similar clays may occur in Indiana County.

The Allegheny group overlies the Pottsville sandstones and averages 300 feet in thickness. This group outcrops in a belt 2 to 6 miles wide along the higher portions of Chestnut Ridge from Bolivar northeast to the corner of the county. Other areas include Black Lick valley east from Black Lick to Wehrum and Vintondale; an area at the west end of Conemaugh Gap in the vicinity of Cramer; small areas at the headwaters of Little Yellow Creek along the Nolo anticline; the Jacksonville region in the southwest part of the county; and small areas along the south branch of Plum Creek and Crooked Creek, Little Mahoning, and Mahoning creeks in the northwest part of the county. The most important coal in the group is the Upper Freeport which is mined extensively in the Chestnut Ridge district. The important fire clays in the Allegheny group lie a few feet below the Upper Freeport coal (the Bolivar clay); below the Lower Kittanning or B coal; and below the Brookville or A coal. Many of the shales of the group are of a quality suitable for the manufacture of building brick.

The Conemaugh group consists of the strata between the Upper Freeport and the Pittsburgh coal beds. It is made up largely of shales with only a few thin coals. Sandstones are abundant in the lower half of the group. The only clay of better quality than brick clay is the clay which underlies the Brush Creek limestone and coal. The horizon is somewhat indefinite but within the strata about 50 feet above the Upper Freeport coal, clays of some value are to be found. They have been termed the Mahoning clays and may lie between layers of Mahoning sandstone or may lie above the Upper Mahoning sandstone. The clay is usually not far below a dark shale which carries a marine fauna and is presumably the Brush Creek limestone horizon. In the older reports the clay was termed the Wehrum clay in its exposures along the Black Lick valley.

The Monongahela group has for its base the Pittsburgh coal bed and includes all the strata in the county above that coal, amounting to a maximum thickness of 217 feet in the southwest portion of the county. The Monongahela strata are found only in an area of about 18 square miles extending from Edri northeast to West Lebanon and including the mining town of Iselin. The higher hills of this area

carry Monongahela shales and limestones and among the shales are some which could be used in brick-making.

These sedimentary strata has been slightly folded into a series of parallel folds whose axes trend in a direction east of north. Some of these structures have considerable influence upon the surface distribution of the rocks, and the Chestnut Ridge anticline has had considerable influence upon the topography. Laurel Hill anticline touches only the southeast corner of the county and Conemaugh Gap exposes the uplifted strata east of Seward. Next on the west is the Barnesboro syncline which passes through Wehrum. Then the Nolo anticline and Brush Valley syncline. West of these is the most important up-fold in the county, the Chestnut Ridge anticline. The axis of this crosses Conemaugh River 2 miles west of Bolivar and continues northeast through Utah, Hortens, Gipsy, Smithton, and leaves the county in its northeast corner. Next to the west is the Latrobe syncline which is not deep enough to admit Pittsburgh coal into the area. West of Indiana are some minor structures but the important structures are the Jacksonville anticline, which brings to the surface outcrops of the Freeport coal in the Jacksonville region; and the Elders Ridge syncline which is responsible for the small field of Pittsburgh coal between Edri and West Lebanon.

CLAY RESOURCES

The clay resources of the county will be discussed by districts and by lines of transportation.

CONEMAUGH RIVER VALLEY

The main line and Conemaugh division of the Pennsylvania Railroad follow the river. In earlier days the Pennsylvania Canal also followed this course but at present river transportation is not possible. Conemaugh strata make the valley walls. Allegheny and older strata are exposed in the gaps through Laurel Hill and Chestnut Ridge anticlines, and the younger Monongahela beds are exposed only near Blairsville and at a little distance from the river near Edri. Among the beds exposed on the west flank of Laurel Hill anticline those of interest to the clay worker include the red shales of the Catskill and Mauch Chunk, and the underclays connected with the Allegheny coals. The Catskill beds are to be seen along the railroad and road near the border line between Cambria and Indiana counties. Sample 358 collected 1 mile east of the Indiana County line is representative. It is a bright red, moderately plastic clay and shale which could be used in the manufacture of red common and face brick and tile.

The Mauch Chunk red beds are also exposed 2 miles west and are similar in character. They are no doubt of similar quality to Mauch Chunk beds tested from other counties (see No. 227). The Allegheny strata are exposed along the railroad from Conemaugh Furnace west almost to New Florence. The Lower Kittanning coal has been mined east of Seward and there is some plastic clay below it. This clay has not been worked and its extent and quality are not known but if it is similar to the usual clay at this horizon it is worth attention. Good outcrops of the Brookville or A coal were not seen but at this horizon clay is to be expected. The clay below the Upper Freeport

and corresponding to the Bolivar clay is of poorer quality than in its exposures farther west and is not used. In the vicinity of New Florence the Allegheny group is below water level and the strata seen are those of the lower 100 feet of the Conemaugh. The clay possibilities here would be the fire clays which underlie the Brush Creek limestone, the red shales which lie higher on the hills, and numerous shales of the upper half of the Conemaugh group which make up the valley walls. Under the influence of the Chestnut Ridge anticline the strata beyond New Florence again rise and the Allegheny group appears east of Lockport. The Upper Freeport coal has been mined near Lockport but the underlying clay is said to be inferior to that at Bolivar and is not worked. Thin clays are present below the other coals of the Allegheny group here, including plastic clay below the Lower Kittanning coal at water level at Bolivar. This or other underclays of that area might be used in the manufacture of buff building brick and sewer pipe but probably are not pure enough for fire brick manufacture. In fact the plant formerly manufacturing fire brick at Lockport used clay from Bolivar.

Below Lockport the strata rise and the 9-foot Lower Kittanning clay is available. This clay is used on the Westmoreland side of the river by the McFeely Brick Company to make buff face brick. At Robinson the Pottsville sandstones lie at river level and the Allegheny strata are exposed in the surrounding hills. This region has for many years been actively engaged in the production of fire brick and other clay products. The clays mined have been the Upper Freeport, Bolivar, Lower Kittanning, and Brookville. Under the Upper Freeport coal there is found here a thin clay followed by shales and sandstone about 10 feet in thickness. Under these and from 11 to 16 feet below the coal is the Bolivar clay which varies from 3 to 12 feet in thickness and includes varying amounts of plastic and flint clay. In general about 5 feet of flint clay can be expected. This is the "hard clay." In many places the clay contains nodules of iron carbonate, termed iron balls, which have to be carefully sorted out. Samples of the Bolivar clay from Robinson were tested by Shaw and described in Bulletin M 10 of the State Geological Survey. Data concerning sample 42 are given in the tables. This clay was obtained from the properties of the Joseph Soisson Fire Brick Company at Robinson. It represents a bed of flint clay 5 feet thick at the Bolivar horizon. This clay is used in the manufacture of fire brick at that point. The sample fused at cone 29 and is termed a good quality No. 2 fire clay. Farther down the hill at Robinson the Lower Kittanning coal outcrops and below it lies 10 to 15 feet of plastic clay which is mined by Joseph Soisson Fire Brick Company and used in the manufacture of building brick. This clay is described in Bulletin M 10 and the physical and chemical tests are also included in the tables in this report. Sample 39 is from the lower 6½ feet of the bed, No. 43 from the middle 4 feet, and No. 44 from the upper 2 feet. All three samples fuse at cone 26 and have good burning qualities. The lower part of the bed seems to be slightly the best material. This is an excellent clay for buff face brick or as a bond clay. Eighty feet below the Lower Kittanning clay and near the river level a third clay is worked. It underlies a thin coal which has been described as the A or Brookville coal and also as the Upper Mercer coal. The author believes it to be the

Brookville coal. Shaw states in Bulletin M 10 that this coal, which he calls Upper Mercer, is underlaid by 5 feet of plastic clay, beneath which there are 4 feet of sandy shales, and 8 feet of plastic clay. Tests and descriptions of these are given in his report but the tests are repeated in the tables accompanying this report. Sample 40 is from the mines of the Garfield Brick Company just west of Robinson. This clay is used in the manufacture of fire brick and is a good quality No. 2 clay. No. 40 is the bottom 8 feet of the clay bed at the same mine. It is a No. 1 clay. No. 41 is the lower 4 feet of the same bed obtained at the Joseph Soisson Co. mine at Robinson. It is a fair quality No. 3 fire clay. Clay working has been the major industry of Robinson and the adjoining town of Bolivar across the river in Westmoreland County and additional notes in regard to the history are given under that county. The excellent location on the Conemaugh Division of the Pennsylvania Railroad and the fact that three clay horizons are available have made it an important center of activity.

West of Robinson the rapid rise of the strata toward the Chestnut Ridge anticline brings to light the heavy sandstones of the Pottsville, followed in turn by the red Mauch Chunk shales, the Pocono sandstones, and a little of the Upper Devonian sandy shales. None of these are of value to the clay worker except possibly the Mauch Chunk red shales which might make building brick. Just east of Strangford the Allegheny strata appear again as the rocks dip westward from Chestnut Ridge. At least two clays of promise were seen across the river east of Torrance (see Westmoreland Co. No. 320) and no doubt good fire clays or buff burning clays are to be found in the Allegheny group east of Strangford. Just west of Strangford the Allegheny group plunges beneath the surface and thence to Blairsville the exposed rocks are of the Conemaugh group in which the most important clay would be the Brush Creek. This and many brick shales should be present between Strangford and Blairsville. At Blairsville the exposed strata are of the upper half of the Conemaugh group which carries a number of good brick clays and shales. Small areas of Pittsburgh coal are present and about 100 feet of the overlying Monongahela shales of small value.

Below Blairsville the river flows through the shales and sandstones of the Conemaugh group for 10 miles or to a point half a mile below Tunnelton. Here the upper portion of the Allegheny group is brought to light under the Jacksonville anticline and the Freeport coals are to be seen accompanied by dark nodular shales of little value. The horizon of the Bolivar clay is shown in this area by 15 feet of impure clay. This clay was used many years ago at Tunnelton for fire brick making but it is too impure for present demands. Further prospecting might bring out some better deposits of it in the stretch between Tunnelton and Whites. Beyond Whites the Allegheny strata dip below the surface and the heavy sandstones of the lower Conemaugh are much in evidence. Near Saltsburg bluish shales are to be found beneath the heavy Saltsburg sandstone. These are not of good quality (see No. 236 Westmoreland Co.) and would not make as satisfactory product as the red clays and shales which lie on the higher hills around the town.

From Saltsburg down Kiskiminetas River (the continuation of the Conemaugh) to the county line below Edri, the strata along the river

belong to the upper half of the Conemaugh group and carry many shales excellent for making brick. The Pittsburgh coal is mined a short distance back from the river.

BLACK LICK VALLEY

Blacklick Creek comes into the county at Vintondale and flows westward more or less parallel with Conemaugh River and a few miles north of it. After meeting Twolick Creek near Black Lick it bends slightly southwest and enters the Conemaugh below Blairsville. The highland between Blacklick and Conemaugh valleys is underlain mainly with Conemaugh strata; Allegheny beds appear along the axis of Chestnut Ridge. This highland is traversed by the William Penn Highway and along it many good shales are exposed. These are the usual type of brick shales common in this series. They are abundant around Armagh.

At Vintondale the Freeport and the Upper Kittanning coals are exposed and thin fire clays accompany them. West from Vintondale the Allegheny strata give way to the overlying Conemaugh group and its shales are seen as far as Dilltown. A sample of buff shale was collected along the road about half a mile north of Wehrum, and it appears in the tests as No. 376. This shale shows good plasticity and low green strength. It burns salmon to dark brown and has a burning range from cone 1 to 8. It is suited to the manufacture of face brick and tile. At Wehrum a clay appears which lies above the Mahoning sandstone and below the Brush Creek coal and the marine Brush Creek shales. This has been called the Wehrum clay. It ranges from 5 to 8 feet in thickness and from a flint clay to a hard plastic clay in quality. From Wehrum to Dilltown it rises until at the later locality it is possibly 100 feet above the stream. It also outcrops up Mardis Run. An analysis of it given in U. S. Geol. Survey Folio 174 (see table at end of chapter) indicates that it is high in iron. This clay is well exposed along the road leading from Dilltown up to the Wm. Penn Highway. The section there shows:

Section near Dilltown

	Feet
Thin black shale with marine fossils	10
Coal	$\frac{3}{4}$
Clay sample No. 377	7
Sandstone and shale	10
Softer shale some reddish	6
Crumbly buff shale and clay	4

Sample 377 is evidently the Wehrum clay although it is not a flint clay. This clay has a fair plasticity and green strength. It burns to a salmon to dark brown color with a firing range from cone 02 to 4. It is suitable for making brick or tile. Below Dilltown the Allegheny group appears above stream level and in the next 4 miles the whole of this group should outcrop. Little is known of the clays in this area but several good fire clays should be present. Near Dias the Pottsville sandstones are at stream level. The position of the clays at that point should be similar to the position of those at Robinson and Bolivar. The complete exposure of the Allegheny group continues to Heshbon, beyond which the river passes into a gap through Chestnut Ridge and a section of the Pottsville, Mauch Chunk, and Pocono rocks is exposed. At the western end of this gap and about 2 miles above

Josephine the Allegheny strata fall to track level again and for a mile the lower beds or the strata between the Pottsville and the Lower Kittanning coal are near rail level. Half a mile above Josephine, Meldren's brick yard was in operation many years ago, using a clay called the Black Lick clay. The section at this plant as recorded in volume HHHH of the Second Pennsylvania Geological Survey is as follows:

Section at quarry near Josephine

	Feet
Lower Kittanning coal	4
Clay	12
Ore shale	3
Poor fire clay	5
Sandstone	40
Brookville coal	3
Shale and clay	10-20
Sandstone	5
Hard clay	3-5
Sandstone	1
Plastic clay	3½
Pottsville sandstone	

The clays in general use when this plant was in operation were the two lower layers, the hard clay and the underlying soft plastic clay. Analyses of these clays are given in the tables at the end of the county description. At present there is no development of clay in this region but with favorable railroad facilities this district deserves renewed exploration. Below Josephine, Blacklick Creek meets Twolick Creek and flows across a wide belt of Conemaugh rocks of no special interest in clay resources and enters Conemaugh River.

Region Between Black Lick and Yellow Creek Valleys.

The divide between these two valleys is an area of high land in Buffington and Brush Valley townships. It is underlain by strata of the Conemaugh group and is of little interest to the clay worker. Good building-brick shales are common and in the lower parts some of the better clays, which are in the horizon of the Brush Creek coal and the Upper Mahoning sandstone, may be of value. Brush Creek cutting into this highland from the south exposes sections of the Allegheny group and there is therefore a chance that fire clays accompanying the Upper Freeport and the Lower Kittanning coals may be discovered.

East of Homer and of the railroad between that town and Black Lick there is a belt of exposures of the Allegheny group which has furnished large amounts of Upper Freeport coal and established an important coal and coke industry in that region. Near the headwaters of Tearing Run all the Allegheny coals are present and probably some fire clays are associated with these, although no development has been done. Little Yellow Creek flows through Pine Township and meets Yellow Creek at the north line of Brush Valley Township. The course of the Little Yellow in Pine Township lies close to the crest of the Nolo anticline and this uplift has brought the Allegheny group to the surface along the entire valley in this township. South of Nolo the stream even cuts down to the level of the Pottsville rocks for a short distance on the crest of the anticline. The Upper Freeport coal is the most prominent coal exposed and little is known

of the clays below it or at the lower horizons. Lack of railroad facilities hinders any development. The lower course of the creek lies in Conemaugh rocks. The upper branches of Yellow Creek also lie in a region of Conemaugh beds in the Brush Valley syncline and are of minor interest. Below the junction of the Little Yellow and Yellow creeks, Yellow Creek flows over a plain of alluvial material and through Conemaugh beds for 2 miles. Then, approaching the Chestnut Ridge anticline, the Allegheny group appears. It should contain some fire clays. After flowing about a mile between these rocks the stream passes into a rough course through a 5-mile stretch of Pottsville and probably Mauch Chunk strata which are brought up under the crest of the Chestnut Ridge anticline. Any clays to be found in this portion of the valley would be high up on the valley walls in the lower Allegheny rocks.

The Pottsville series dips westward toward the Latrobe syncline and is last seen about 3 miles above Homer. Thence the stream is bordered with Allegheny rocks to a point about 1 mile above Homer where it passes into Conemaugh strata. The lack of a railroad has hindered exploration of the Yellow Creek Valley and we can say but little about its clay resources. The Allegheny strata in the valley from 1 to 5 miles northeast of Homer should yield fire clays suitable at least for face brick manufacture.

TWOLICK VALLEY

Twolick Creek rises in northern Greene Township and its main northern tributary, Dixon Run, rises in northern Rayne Township. Both are in the region of the Chestnut Ridge anticline and cut down into the beds of the Allegheny group. The Upper Freeport, Lower Freeport, and Lower Kittanning coals have been mined in these districts. Clays accompanying these coals have not been prospected or worked along these valleys but some, no doubt, are present, especially under the Lower Kittanning coal. West of Mitchells Mills, Twolick Creek crosses the axis of Chestnut Ridge anticline and the lower part of the Allegheny group and the upper part of the Pottsville sandstones are exposed in the gap. The Lower Kittanning coal is well exposed here and beneath it there is a plastic clay said to be 32 feet in thickness although this no doubt includes much shale. This clay was at one time used by the Clymer Brick and Fire Clay Company in the manufacture of hollow, paving, and building brick. It was mined on the south side of the stream about 1 mile above the mouth of Dixon Run (see Folio 189). This is just east of Clymer. Southwest from Clymer for some 10 miles the stream flows practically parallel to the strike of the beds and the Lower Kittanning coal lies near stream level with the Upper Freeport coal higher in the hills. This is on the western edge of the Chestnut Ridge area of Allegheny coals and to the west over much of the county the surface strata are of Conemaugh age. The coals in this part of Twolick valley are only partly developed on account of lack of railroad facilities and the clays have never been developed at all. Buff building brick and possibly low grade fire brick could be made from these clays under the Freeport and Lower Kittanning coals.

NORTHEASTERN TOWNSHIPS

The eastern part of the region is drained to the east by Bear Run and by Cush Creek. The western part drains west into Little Mahon-

ing Creek. The surface strata are chiefly Allegheny, the Conemaugh appearing only in the divides and higher hills. Coal mining therefore is extensive and clay possibilities are better than in most of the county. All of the coals are present, with the following intervals between them and the coal next below.

	Feet
Upper Freeport	30-35
Lower Freeport	35-40
Upper Kittanning	55-80
Middle Kittanning	55-60
Lower Kittanning	70
Brookville	

Ashley in the report on the Punxsutawney Quadrangle (Pa. Geol. Survey Atlas No. 65) notes the presence of clay with these coals in various localities which are plotted on the map accompanying the report. The Upper Freeport clay in eight exposures ranges from 3 to 8 feet thick; the Lower Freeport clay in three places ranges from 1 to 8 feet thick; and the Lower Kittanning clay in three outcrops is 2 to 6 feet thick.

Flint clay was noted at the Lower Kittanning horizon at two places on the south branch of Bear Run 3 miles north of Smethport, and Mercer flint clay was seen above Sidney Station where Bear Run leaves the county. Further exploration would be necessary to determine the extent and quality of the clays. Flint clay was also seen at the Upper Freeport or Bolivar horizon at the following localities; $1\frac{1}{2}$ miles north of Deckers Point; $\frac{3}{4}$ of a mile south of Rochester Mills; 2 miles northeast of Enterprise; 1 mile southwest of Nashville; 1 mile east of Robertsville; 1 mile northwest of Gipsy. Lower Kittanning flint clay was observed just south of Robertsville.

Olive shale grading into impure flint clay occurs in a similar position to that of the Wehrum clay, that is, above the Mahoning sandstone. This clay occurs frequently in the area and may be of value. For further details of this region the Punxsutawney atlas should be consulted. Further prospecting may disclose fire clays of value, and brick clays can be obtained in this district.

NORTHWESTERN TOWNSHIPS

The four northwestern townships are drained principally by Mahoning and Little Mahoning creeks. The region is rolling farm lands. The surface is practically all made up of the Conemaugh strata and the soft shales furnish good soil. Clays are not worked in the district but there are plenty of shales which could be utilized for making brick and tile. The coals and clays in the Allegheny group come to the surface only in two areas, along Little Mahoning Creek a few miles southeast of Smicksburg, and on Mahoning Creek in the corner of the county. The strata here exposed are mainly the Upper Freeport coal and a little of the shales and limestones beneath this bed. The underlying clay has not been noted but it is likely that flint and other fire clays occur under the Upper Freeport coal in these areas.

REGION AROUND INDIANA

West of Chestnut Ridge and the coals of the Allegheny group on its western flank the county is largely underlain by Conemaugh rocks. Small areas of the underlying Allegheny group and of the higher Pittsburgh coal occur. North from Indiana the hills contain abundant

shales, including much red clay and shale of the Ames limestone horizon. About 2 miles north on the DuBois road an outcrop of the Ames limestone was seen and a sample taken of the overlying red clay and shale. This sample (No. 126) shows good plasticity and high green strength. It fires to a red color with a burning range from 1000 to 1200° C. or approximately cone 07 to 4. The clay is suitable for the manufacture of face brick, common brick, sewer pipe, and fireproofing. This indicates that the red beds near Indiana are of excellent quality and are probably the best clays in the vicinity. On the Clymer road similar clays were seen near Indiana and 2½ miles from Indiana black and gray shales were noted along the road. A sample of these (No. 238) shows fair plasticity and low green strength. It burns to red or brown but shows poor burning properties. It seems of doubtful value unless it could be mixed with other clays. This or similar shale predominates between this point and Clymer. Still farther north from Indiana small areas of Allegheny rocks appear on Sugarcamp Run and the south branch of Plum Creek near Willett, and on Crooked Creek one mile east of Chambersville. The Upper Freeport coal is exposed and there is a chance that its underclays may be of good quality although little is known of them.

West from Indiana sandy shales and red beds predominate and the red beds seem to be the best material available for making brick. Half a mile west of Shelocta a section was measured.

<i>Section near Shelocta</i>		Feet
Nodular iron shales		20
Shale carrying marine fossils		3
Brush Creek limestone		1
Dark shale		6
Brush Creek coal		¾
Light clay		7

The clay at the bottom of this section evidently is the same as the Wehrum clay; it is hard and micaceous in places and is replaced by shales at some points. Further prospecting might disclose a good clay but that seen did not seem worth sampling.

South and southwest from Indiana the Conemaugh strata are the surface rocks over much of the district and many good shales are available. The Ames limestone appears in many places and east of Clarksburg or 5 miles from Saltsburg on the Saltsburg-Indiana road this limestone is seen underlain by 1 foot of the Harlem coal and this in turn underlain by 3 feet of clay (No. 237). This clay burned brown and showed fair plasticity. It fused at cone 13, so it is not a fire clay. It might be used in the manufacture of face brick but like many of the clays below limestones in the Conemaugh group, it may be difficult to burn properly. The red beds above the Ames limestone are present in the vicinity and could be used for brick-making. That region is served by the Buffalo, Rochester & Pittsburgh Railway, which connects Iselin with Indiana.

The Jacksonville anticline brings to the surface the upper half of the Allegheny group in the vicinity of Kent and Jacksonville along Aultmans, Reed, and Coal runs. The Upper Freeport coal averages 4 feet thick and the Lower Freeport may be 5 feet thick. Volume HHHH of the Pennsylvania Second Geological Survey gives the section along Coal Run:

Section on Coal Run

	Feet
Upper Freeport coal	4
Clay	6-8
Limestone	6
Fire clay and shale	10

This indicates that the Upper Freeport and Bolivar clays are present but the Bolivar clay seems mixed with ferruginous shale and probably is not of good quality.

West of Jacksonville and in the southwest corner of the county there is an area covered by the Pittsburgh coal and 217 feet of overlying strata. The coal is mined at Iselin, Edri and elsewhere but no clay accompanies it nor are there any very good shales above it.

SUMMARY

It is thus evident that Indiana County is underlain chiefly by the Conemaugh group which contains abundant brick shales and some better brick material in the red beds. The Allegheny group along Chestnut Ridge has furnished some good flint and plastic fire clays from the Upper Freeport, Bolivar, Lower Kittanning, and Brookville horizons and these are especially important in the stream gaps through Chestnut Ridge. The northeastern townships show prospects of flint clay and plastic clay in the Allegheny group. Robinson on Cone-maugh River is the only place in the county where clay is being used in 1931.

Table 16

Physical tests of Indiana County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slaking in minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested uses
38	24.8	-----	5½	-----	-----	9	30	For Full Data on No. 38-44 see Bul. M10	Buff	fire clay
39	23.3	-----	3	-----	-----	9	26		Buff	face brick
40	24.4	-----	7	-----	-----	9	32		Buff	fire brick
41	24.9	-----	4½	-----	-----	9	26		Buff	fire brick
42	21.6	-----	4	-----	-----	11	29		Buff	fire brick
43	22.5	-----	11	-----	-----	9	26		Buff	face brick
44	21.0	-----	3	-----	-----	9	26		Buff	face brick
126	23.6	6.0	7	322	10.4	02	12	07-4	Lt. to dark red	face brick, sewer pipe, fire proofing
236	20.0	3.4	4	112	10.7	1	8	-----	Red to brown	doubtful value
237	-----	-----	-----	-----	-----	-----	13	Poor	Buff to brown	possibly face brick
238	25.3	3.2	7	101	6.3	02	12½	Poor	Red to brown	doubtful value
358	21.0	5.2	6	269	6.8	6	15	05-1	Red-brown	Brick and tile
376	22.5	3.6	5	198	7.7	8	18	1-8	Salmon-dark brown	face brick and tile
277	22.9	5.5	5	283	7.9	1	16	02-4	Salmon-dk. brown	Brick and tile

Table 17

Chemical analyses of Indiana County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
38	10.22	53.62	.52	-----	32.71	.21	.29	-----	-----	.24	-----	-----
39	8.55	54.90	1.92	1.64	28.45	.50	-----	-----	-----	-----	-----	-----
40	7.90	58.38	2.88	1.19	27.65	.41	1.08	.31	.20	-----	.08	.15
41	9.37	63.56	4.71	1.05	19.96	.87	.46	-----	-----	.02	.08	.17
42	8.34	53.24	2.61	.86	32.85	.63	.82	.32	.23	.15	.18	2.86
43	4.83	69.92	4.63	.89	16.83	.59	.42	.93	.45	.04	.15	.32
44	6.15	62.75	2.72	2.43	21.55	-----	.66	-----	-----	-----	-----	-----
126	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
236	7.09	52.86	6.75	.50	23.86	2.37	3.19	-----	-----	.32	.06	-----
237	6.26	62.37	6.23	.97	20.59	1.27	2.61	1.06	4.11	.05	.52	.10
238	7.79	58.43	-----	-----	-----	1.41	1.86	-----	-----	-----	-----	-----
358	4.22	60.32	18.32	1.09	7.18	.53	.20	-----	-----	-----	.10	-----
376	5.76	57.46	9.25	2.38	20.91	.42	.28	1.57		.02	.18	.80
377	6.76	55.51	7.54	.63	20.62	1.51	2.25	2.22	1.06	.11	.15	.13
A	9.39	64.83	.90	.88	23.95	.11	.18	.29		-----	-----	-----
B	6.31	68.49	1.56	2.15	18.46	.23	.55	2.75		-----	-----	-----
C	12.05	50.84	3.21	1.26	30.74	.16	.28	.54		-----	-----	-----
D	7.83	59.83	1.65	1.17	24.58	.28	.87	3.11		-----	-----	-----
E	12.00	50.3	10.4	.99	21.3	.39	.61	1.14	.18	-----	-----	-----
F	10.20	53.10	3.08	1.20	27.80	.22	.60	3.58	.48	-----	-----	-----

Localities from which Indiana County clay samples were obtained.

38. Plastic clay, Garfield Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
39. Plastic clay, Jos. Soisson Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
40. Plastic clay, Garfield Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
41. Plastic clay, Jos. Soisson Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
42. Flint clay, Jos. Soisson Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
43. Plastic clay, Jos. Soisson Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
44. Plastic clay, Jos. Soisson Fire Brick Company, Robinson. Pa. Geol. Surv. Bull. M10.
126. Red shale, along road 2 miles north of Indiana.
236. Shale west of Saltsburg, in Westmoreland County.
237. Clay below Ames limestone, 5 miles east of Saltsburg along Indiana road.
238. Shale 2½ miles north of Indiana on Clymer road.
358. Catskill red beds, Conemaugh Gap, 1 mile east of Indiana County line.
376. Buff shale ½ mile north of Wehrum on Vintondale road.
377. Wehrum clay south of Dilltown on road to Wm. Penn Highway.
- A. Hard clay east of Josephine. Pa. Second Geol. Surv. vol. HHHH, p. 194.
- B. Soft clay east of Josephine. Pa. Second Geol. Surv. vol. HHHH, p. 194.
- C. Hard Bolivar clay, Bolivar. Pa. Second Geol. Surv. vol. HHHH, p. 90.

- D. Soft Bolivar clay, Bolivar. Pa. Second Geol. Surv. vol. HHHH, p. 90.
- E. Wehrum clay, Dilltown. U. S. Geol. Surv. Folio 174, p. 13.
- F. Lower Kittanning clay, Seward, Westmoreland Co. U. S. Geol. Surv. Folio 174, p. 13.

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- Sisler, J. D., Bituminous Coal Fields of Pennsylvania: Pennsylvania Top. and Geol. Survey, Bull. M6, Pt. 2, 1926. Pages 283-304 describe the coals in Indiana County.
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U. S. Geol. Survey Atlas, Elders Ridge Folio No. 123, 1905.

LAWRENCE COUNTY.

Lawrence County lies just north of Beaver County and south of Mercer County. New Castle, its county seat and largest city, is in the center of the county. The topography is that of typical glaciated areas, rolling hills and wide valleys with few rock exposures. The uplands are between 1200 and 1300 feet above sea level and the larger streams flow at 750 to 800 feet, giving a relief of 500 to 600 feet. The principal streams of the county are the Shenango, Mahoning, and Beaver rivers, all of which are flowing in pre-glacial valleys whose rock bottoms are far beneath the present stream. The unconsolidated deposits which fill these old channels are in some places 200 feet deep. Beaver River has cut a more recent channel below the level of the pre-glacial valley and now flows in a rocky gorge, bounded on either side by a high, wide terrace covered with glacial gravel and representing the original pre-glacial valley. Shenango River comes in from the northwest and flows in a southerly direction past New Castle, below which it joins the Mahoning and becomes the Beaver River. Mahoning River flows from the west and joins the Shenango just

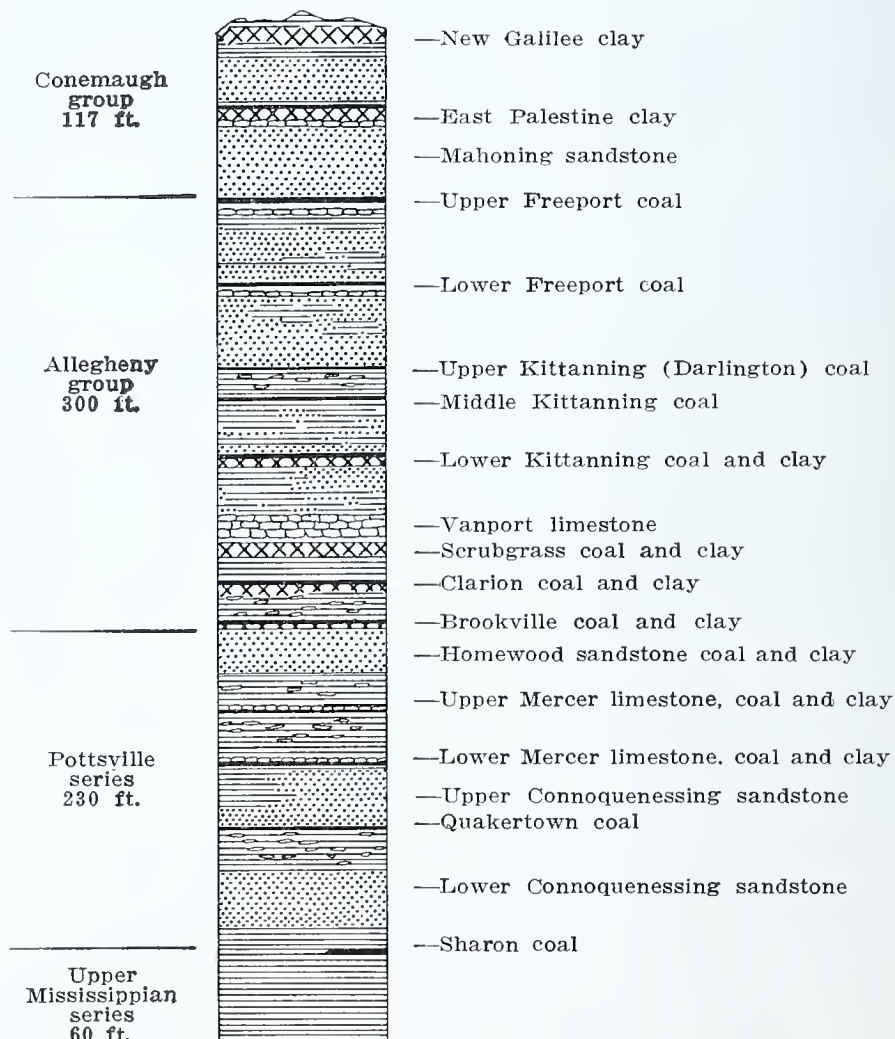


Fig. 15. General section of strata of Lawrence County,

below Mahoningtown. The Beaver from that point flows south past Wampum and into Beaver County. The other streams of the county are in part flowing in old buried courses, as is the Little Beaver of the southwestern corner of the county, and in part flowing in rugged post-glacial courses, as do the Connoquenessing and Slippery Rock creeks. Some of the pre-glacial drainage has been completely buried and the post-glacial streams have sought other courses. Neshannock Creek flows from the northern border of the county and meets Shenango River at New Castle. The eastern borders of the county are largely drained by Slippery Rock Creek which joins Connoquenessing Creek near Wurtemburg and this, in turn, empties into Beaver River at the Beaver-Lawrence County line.

STRATIGRAPHY

The rocks of the county are sedimentary strata lying practically horizontal. They range from strata of lower Conemaugh age down to shales just below the Pottsville series and therefore Mississippian in age. Altogether there are exposed about 745 feet of strata, including 150 feet of lower Conemaugh, 290 feet of Allegheny, 245 feet of Pottsville, and perhaps 60 feet of Mississippian shales below the Lower Connoquenessing horizon of the Pottsville. Much of this section is obscured under glacial deposits and in some parts of the county outcrops are very rare. A very general section of the strata is as follows: (see also Fig. 15)

General geologic section in Lawrence County

	<i>Feet</i>
Conemaugh group	
Concealed; carries the New Galilee clay horizon	20
Massive sandstone	30
Shales	5
East Palestine coal (Brush Creek)	4
East Palestine clay	3
Limestone	5
Concealed; chiefly shaly Mahoning sandstone	50
Allegheny group	
Upper Freeport coal	4
Upper Freeport clay	2
Upper Freeport limestone	8
Upper Freeport sandstone or shale (Butler)	50
Lower Freeport coal	5
Clay	2
Lower Freeport limestone, often absent	1
Freeport sandstone, usually shaly	50
Upper Kittanning coal (Darlington bed)	2
Dark shale with iron nodules	20
Middle Kittanning coal	2
Middle Kittanning clay	3
Shale, often sandy	40
Lower Kittanning coal	2
Lower Kittanning clay, ranges from 5 to 12 feet	6
Kittanning sandstone or shale	30
Buhrstone iron ore, 0-10 feet	2
Vanport limestone	15
Shale	3

	<i>Feet</i>
Scrubgrass coal	2
Scrubgrass clay, at times 5 feet	1
Shale	20
Clarion coal	1
Clarion clay	3
Shale with iron nodules	25
Brookville coal	2
Brookville clay	2
Pottsville series	
Homewood sandstone (formerly Piedmont or Tionesta)	30
Homewood coal	3
Homewood clay	4
Homewood shale with iron nodules	20
Upper Mercer limestone (formerly Upper Wurtemberg)	2
Upper Mercer coal	1
Upper Mercer clay	3
Upper Mercer shale with iron nodules	20
Carbonate iron ore	1
Lower Mercer limestone	2
Lower Mercer shale or clay	6
Lower Mercer coal	1
Shale or some clay	8
Upper Conoquenessing sandstone	40
Quakertown coal	1
Clay	1
Shale with iron nodules	30
Lower Conoquenessing sandstone	40
Dark shale, Sharon	20
Sharon coal or but a trace	0
Mauch Chunk series	
Shales probably Mississippian age	60

It will be noted that the coals are thin and usually hardly workable; that the clays are usually thin; that the sandstones are extremely variable, thickening and thinning very suddenly; and that there are three marine limestones, the Vanport, Upper and Lower Mercer, which are good key horizons.

As seen from the map (Pl. 1) these groups of strata are distributed about as follows:

The Conemaugh is found only on the tops of a few of the southern hills, especially those west and south of Coverdale. It is usually weathered and obscured under glacial material.

The Allegheny group covers almost all the upland territory of the southern half of the county and the higher hills in the northern half of the county.

The Pottsville series forms the rock walls of practically all the major valleys and widens until it occupies much of the higher lands of the northwest corner of the county. The lowest divisions of the Pottsville and the underlying shales are to be seen along the Mahoning and Shenango rivers.

The clay and shale resources of the county can best be discussed by dividing the county into natural subdivisions.

CLAY RESOURCES

WEST OF BEAVER AND MAHONING RIVERS

This is a rolling, glaciated region given over largely to agriculture except along the two rivers. It is served in the south, Enon Valley area, by the Pittsburgh, Fort Wayne & Chicago division of the Penn-

sylvania Railroad. Along the Beaver and Mahoning rivers it is served by the Pennsylvania Railroad and by the Pittsburgh & Lake Erie Railroad. Branch railroads lead in from Covert to Bessemer and from Wampum to Coverdale. Along the Beaver and Shenango rivers the strata are all of Pottsville age while back from the rivers on the uplands the rocks are practically all of Allegheny age with only the few scattered hills high enough to carry any Conemaugh strata. In the Conemaugh areas it is possible that workable clay or shale will be found although the deposits are now largely obscured. In the vicinity of Cannelton in Beaver County the clay below the East Palestine or lower Brush Creek coal is used in the manufacture of brick and fireproofing and a test was made of it (No. 173). It should be found about 55 feet above the Upper Freeport coal. The great expanse of Allegheny strata on the uplands has not been explored in detail because much of it is some distance from a railroad and not very rich in coal. In the neighborhood of Enon Valley, which has good railroad facilities, the Lower Kittanning coal and clay lie practically at river level and it seems probable that this valuable clay could be mined here as it has been at New Galilee and Darlington in Beaver County. Two miles to the northwest it has been reported as 6 to 10 feet thick, growing sandy at the base. Samples 172 and 175 from Beaver County indicate its usual qualities. Excellent face brick are made from it and it might also be used in the manufacture of low heat duty fire brick and other products. Shales just above the Lower Kittanning coal are used at New Galilee in admixture with the clays, and tests of the shale (No. 174) indicate that it can be used alone for face brick manufacture.

In the vicinity of Wampum and west to Coverdale the quarrying of the Vanport limestone has produced an industrial development which has uncovered many sections of the Allegheny series and the underlying Pottsville beds. At the quarry of the Crescent Portland Cement Company at Wampum the Lower Kittanning clay is seen to a thickness of 7 feet, lying about 30 feet above the Vanport limestone. The Middle Kittanning clay 35 feet higher shows a thickness of 5 feet. At Coverdale this latter bed is 2 to 3 feet thick. It would seem that the Wampum region might develop these clays as successfully as they have been mined elsewhere. There is also abundant shale of a brownish-gray color above the Vanport limestone at this locality. No test was made of it but from an analysis furnished by the Crescent Portland Cement Company, who use it in their cement mixture, it should burn to red and make satisfactory brick. The analysis follows¹: SiO_2 -64.61, Al_2O_3 -20.90, Fe_2O_3 -9.98, CaO -47, MgO -1.04, SO_3 -1.93. Below the quarry level there is a possibility of encountering the clays under the Homewood sandstone and the Mereer coals. Three feet or more of a clay which is probably the Homewood was seen at the underpass on the road south from Wampum.

Edwards Run, which joins Beaver River at Moravia, exposes various interesting clays. One mile west of Moravia the Lower Mereer limestone and coal are underlain by 4 feet of fire clay and just west at the forks a 5-foot sandy fire clay is seen under the Homewood coal. Near by, the Upper Mereer coal carries beneath it a 5-foot clay. These

¹ Pennsylvania Geol. Surv. 4th ser., Atlas 5, p. 186, 1929.

clays are noted in Atlas 5, Pennsylvania Geological Survey and are said to be siliceous and non-plastic.

Below Mt. Jackson, on Hickory Creek, the Homewood clay was also noted, and between Mt. Jackson and Mountair the Lower Kittanning clay is 7 to 12 feet thick.

Six miles west of Mahoningtown lies Bessemer, which is connected by rail with Covert. At Bessemer there are extensive quarries in the Vanport limestone, and both limestone and Portland cement are produced. The shale above the limestone is used by the Metropolitan Paving Brick Company in the manufacture of paving brick and face brick. The section shown in their quarry is as follows:

Section in quarry at Bessemer

	Feet
Glacial clay and gravel	3
Shale	3
Coal, Lower Kittanning	1
Clay, Lower Kittanning	4
Shale	3
Blue shale, sample No. 180	15

The material above the 15-foot bed of shale is stripped away as it is a weathered mixture of uncertain quality. Some of it is allowed in the final mixture, more in the material which goes to the face brick plant. The tests show that the shale has good plasticity, low green strength, and that it fires to a buff to dark brown with a burning range from cone 1 to cone 6. It shows little shrinkage and keeps a high porosity to cone 1. The addition of some of the upper material is seen to be desirable. The paving brick plant is in the east end of the town. It was built in 1907 and very much enlarged in 1914. The shale is brought to the plant from the quarry by steam locomotives and placed in a storage shed with 25,000 tons capacity. It is ground with a 24-by 60-inch Fairmont type single roll and two 15-by 40-inch Anaconda type rolls and dry pans of Bonnot make. Two redesigned Hoffman continuous kilns are used in burning the ware. These kilns are 1600 feet long and fired with slack gas coal from both side and top. Two hundred twenty-five men are employed and 750 tons of ware turned out a day. The face brick plant is in the west end of the town. It gets its clay from the same quarry as the other plant, and burns it in 13 square, multiple-stack, Wilson down-draft kilns. Their capacity is 100,000 brick per day and they employ 80 men.

This company does not use the Lower Kittanning clay but in all directions from Bessemer it has been reported as 5 to 12 feet thick. Two miles north of Bessemer it was at one time shipped.

In Mahoning Valley to the north the Vanport limestone is 300 to 350 feet above the river, and the exposed rocks on the valley walls are part of the Pottsville series. The principal clays here are at the Mercer horizon. At Hillsville a 5-foot clay below the Upper Mercer coal was formerly made into fire brick (Rept., QQ, p. 227) and there is also a 7-foot clay below the Lower Mercer limestone and above the Lower Mercer coal. These clays are siliceous and non-plastic. About 1 mile west of Edinburg is the plant of the Mahoning Shale Products Company of Lowellville, Ohio. This plant is on the north side of the river on the Baltimore & Ohio Railroad. It was idle at the time of our

visit and they were doubtful about reopening. The material used was a dark shale from a quarry above the plant. The section at the quarry showed as follows:

Section in quarry at Edinburg

	Feet
Glacial gravels	15
Very white sandstone	4
Dark gray to black shale	12
Sandstone	2
Dark shale	6

No doubt the sandstone layers and the overlying gravel gave them considerable trouble. The product made was a light-pink, hollow tile. The shale was molded in a Freese machine and burned in 9 round and 1 square kilns. This shale seems to be about 260 feet below the Vanport limestone and is probably a Sharon shale.

Most of the exposures along the Mahoning Valley are of sandstone, shaly sandstone or dark shale of little promise, and unless some of the Mercer clays are found to be of value, probably little clay development can be expected.

BETWEEN MAHONING AND SHENANGO RIVERS

The high divide area between the Mahoning and the Shenango rivers shows few outcrops on account of heavy glaciation and is an agricultural region. Along Mahoning River, as already pointed out, the Vanport limestone forms the upper stratum along the hilltops and the river has cut down through about 390 feet of strata, exposing all of the Pottsville series and dark shales at the base which are either Sharon shales of the lower Pottsville or upper Mississippian strata. Quaker-town Run, Coffee Run, and Welsh Run enter the Mahoning from the north and along them there are numerous exposures of the series. Fire clays, probably very siliceous, underlie the Homewood sandstone, and the Upper and Lower Mercer coals of this section and were worked many years ago for the early iron industry. No operations are now going on and good exposures are rare. In the higher lands back from the Mahoning there are some knobs high enough to take in the Lower Kittanning coal and probably also its clay. Between Covert on the Mahoning and New Castle on Shenango River there is a high, sharp ridge or divide. This carries small areas of the Kittanning beds at a point 2 to 3 miles west of New Castle. Report QQ notes the mining of fire clay 4 miles west of New Castle on the old New Castle and Youngstown road from the Upper Mercer horizon for use in the furnaces of Ries, Brown, and Bergher at New Castle.

The northwest corner of the county, Pulaski Township, is largely covered with glacial deposits and has very few rock outcrops. Shenango River also flows on glacial fill and shows few outcrops of rock along its banks. The highest rocks exposed in the area are the Homewood sandstone or upper Pottsville. This indicates that there is a possibility of uncovering the Mercer coals and clays throughout the higher parts of the township. Aside from these there are a few shales from which brick may be manufactured, and some of the better grades of glacial clays might be used for the manufacture of common brick or drain tile.

BETWEEN SHENANGO RIVER AND NESHANNOCK CREEK

This area is very much like the area west of Shenango River. In the higher part of the divide, small areas of Kittanning strata are present and below them the Vanport limestone. Their outcrops however, are obscured with glacial drift. At the river levels upper Mississippian strata are exposed. Between New Castle and New Wilmington a few thin coals at the Homewood and Mercer horizons have been mined but no clays of any importance were noted with them. In the vicinity of New Wilmington similar coals have been worked. Three-quarters of a mile west of New Wilmington on the West Middlesex road a shale was sampled (No. 223). This is an olive and blue shale about 10 feet thick and is probably a Mercer shale. Tests show it to have fair plasticity and low green strength. It fires to a salmon to red brown color and its best burning range lies between cones 010 and 03. It seems fitted for the manufacture of drain tile and common brick. The glacial clays of northern Lawrence County were not tested but a test was made of a typical till from a bank 2 miles north of West Middlesex in Mercer County (No. 224). It seems fitted for the manufacture of common brick and drain tile and no doubt many of the glacial clays around northern Lawrence County could be used for similar purposes.

Neshannock Creek, in contrast to Mahoning or Shenango rivers, flows on a rock bottom and has carved a rugged channel for itself through the heavy sandstones of the lower Pottsville. The cliffs along it are chiefly of the Upper and Lower Connoquenessing sandstones, the shales and possibly clays of the Mercer horizons lying high above the stream. Clay is not mined on the western side of Neshannock Creek.

EAST OF NESHANNOCK CREEK

This district includes the eastern slopes of the Neshannock valley, a high central area or divide, and to the east, a part of Slippery Rock Creek and some of its tributaries. The two main streams are bordered by Pottsville rocks, the Vanport cropping out back from the streams from $\frac{1}{2}$ to 2 miles. The higher land away from the streams carries strata up to and perhaps above the Middle Kittanning coal bed, but the main exposures are of glacial drift.

In the eastern part of New Castle there are many quarries in the Vanport limestone and therefore good exposures of the strata above and below it. Three-quarters of a mile east of the end of the trolley line on Croton Street on the Harlansburg road is the plant of the New Castle Mining and Clay Products Company. This plant is using a mass of shale stripped from above the Vanport limestone during the quarrying of the limestone for cement manufacture some years ago. No. 221 is an average sample of this material as it is shoveled from the dump with a steam shovel. It has good plasticity and green strength. It fires to a red color with the best firing range between cones 08 and 02. Below the plant the company also has a clay mine exposing 12 feet of clay under 22 inches of coal. This is probably the Clarion coal and clay. The clay has a drab color with the exception of the upper 2 feet which is darker. Sample 222 of this clay shows good plasticity and fair green strength. It fires to a cream, buff, or gray color with a firing range from cone 02 to 4, and it fuses at cone 20. This makes it a low grade fire clay but an excellent clay for face brick.

At present the company is making only red face brick from the shale and sending them to eastern markets but they have in the past made buff brick from the clay. The red brick are burned to cone 09 and the buff brick to cone 03. When the latter are burned to cone 3 or 4 they tend to become gray and to show iron spots. The plant is equipped with a dry pan, a Freese auger machine, and 10 round, coal-fired kilns.

About one mile northeast of this plant on the Eastbrook road is the brick plant of the Pearson Brick Company of New Castle. This lies along the east bank of Neshannock Creek west of the road. The quarry is one-quarter of a mile east and connected to the plant by a tram road. The quarry shows from a few inches to 2 feet of the Lower Kittanning coal underlain by 3 feet of fire clay, and that in turn underlain by 15 to 20 feet of dark to light buff shales. These must lie almost directly on the Vanport limestone which outcrops near by. During the quarrying operations, the clay is allowed to mix with the shale; the coal is absent or so thin as to give little trouble. The mixed material as used is sample 183. It has good plasticity and low green strength. It fires to light red to brown with a firing range of cone 1 to 6. The shale is ground in dry pans, molded with a Freese auger machine, and burned in 8 coal-fired, round kilns. Red face brick are the principal product.

Farther up the Neshannock valley similar shales occur with the Vanport limestone and at a distance back from the river one to two miles. Closer to the stream heavy sandstones of the Pottsville predominate. At Volant, near the northern border of the county, Mercer shales are exposed and the Pearson Brick Company of New Castle had a brick plant (burned down in 1930). The plant site and quarry lie just south of Volant, the quarry one-eighth of a mile southeast of the plant and connected by a gasoline tram road.

Section in quarry at Volant

	Feet
Glacial boulder clay	8
Cross-bedded sandstone	8
Bluish to black shale	10
Fossiliferous limestone	2
Whitish clay and light shale	2
Dark shale	4
Whitish clay and light shale	5-8
Blue shale	7-8
Carbonate ore	$\frac{3}{4}$
Dark bluish shale	8

These strata probably are at the Mercer horizon. The ore was mined in the early days as an iron ore and the old drifts are encountered in the present quarrying. No. 181, the white clay and shale, shows fair plasticity and low green strength. It fires to light to dark buff with a firing range from cone 1 to 8, and it fuses at cone 18. It is suitable for the manufacture of light buff face brick or hollow tile. No. 182, the lower blue shale, shows poor plasticity and low green strength. It fires to pale red to brown and has a burning range from cones 1 to 6. It seems suitable for face brick manufacture. In practice the shale and the overlying clay and shale are taken out as one and the resultant mixture has a better plasticity than No. 182 alone. The plant was equipped with two Stevenson dry pans, a Freese auger machine, and 8 coal-fired round kilns. The product was hollow tile.

Little is known about the clays of the higher land back from Neshannock and Slippery Rock creeks. The Kittanning coals are known to be present and in all likelihood the Lower Kittanning coal has below it the usual fire clay of value. Report QQ mentions a bed of this clay 10 feet thick on the Hickory Township line east of Croton. This report also notes a 10-foot bed of the Scrubgrass clay on Taylors Run in Plain Grove Township. Glacial drift covers most of this higher land.

Slippery Rock Creek cuts down into the upper beds of the Pottsville in eastern Scott Township and the Vanport limestone lies 80 to 100 feet above the stream. This makes available the Lower Kittanning clay, the shales above the Vanport limestone, and possibly clays of the Scrubgrass, Clarion, or Brookville horizons. Glacial deposits obscure these, however, and little is known about them. Just west of the Butler-Lawrence County line on the Harlansburg road a shale cliff was sampled (No. 220). This is an olive shale, probably below the Vanport horizon. It has good plasticity and fair green strength but shows poor firing properties, swelling badly at cone 07. This makes it of no value. In the vicinity of Harlansburg the normal shales above the Vanport limestone seem to be replaced by sandstone.

EAST OF BEAVER RIVER

This district takes in the eastern slopes of the Beaver valley and its tributaries, Big, McKee, Snake, and Spanglers runs; the Connoquenessing valley from its mouth to its union with Slippery Rock Creek; Slippery Rock Creek from Wurttemberg to Rose Point and beyond; and the intervening highlands. This area is within the glaciated zone with the exception of that part south of a line from Rose Point to Wampum. Beaver River, and Connoquenessing and Slippery Rock creeks flow largely between walls of heavy Pottsville sandstones and the Vanport limestone borders the valleys at an average elevation above the streams of 200 to 300 feet. It is seen at the headwaters of most of the tributary streams. The intervening highlands carry practically all of the Allegheny strata but only the higher hills show much above the Kittanning division.

Along the Beaver valley from Mahoningtown to the mouth of the Connoquenessing there is little of interest in the Pottsville series. No doubt the Homewood and Mercer clays are present but they are not usually seen, sandstone being the predominant rock. One mile south of New Castle Junction a shale and clay, probably of the Quakertown horizon, were formerly used for making brick and this is the only clay-working operation along the valley. The river terrace is gravel-covered and this gravel obscures some of the strata of upper Pottsville and lower Allegheny age. Back from the river in the upper slopes of the valley the important industry is the quarrying of the Vanport limestone. This limestone has above it a good quality of shale and above that the Lower Kittanning clay with its usual thickness. These, with the possible occurrence of Scrubgrass or Clarion clay below the limestone, constitute the best possibility as far as clay is concerned. Elsewhere there are used in the manufacture of low grade refractories, sewer pipe, and face brick and might well be used in this district in connection with the limestone industry.

The tributaries which flow into Beaver River are bottomed in their

lower portions by the Homewood sandstone, above which the clays of the Kittanning series are present. On Spanglers Run a 12-foot bed of clay below the Middle Kittanning coal has been reported. The Big Run valley is practically all in Pottsville rocks and there is a chance of finding the Homewood or Mercer clays. At Cascade Park a shale (No. 226) resting on the Upper Connoquenessing sandstone along the Buffalo, Rochester & Pittsburgh Railroad was sampled. It showed fair plasticity and low green strength. It fired to a red or brown with a firing range from cone 010 to 02. It seems suited to the manufacture of common brick and drain tile. Beneath the glacial deposits there should be many shales and clays of the lower Allegheny group along the B. R. & P. R. R. east of Joyce. The upland area from Joyce to Energy and Princeton is glaciated and few exposures are seen.

Along the Connoquenessing from its mouth to its junction with Slippery Rock Creek the rocks seen are chiefly the Connoquenessing sandstone. The Vanport limestone lies 270 feet above the stream and the Lower Kittanning clay still higher. The value of this clay and its underlying shales is well shown for this vicinity in tests made on these beds at the plant of the Clydesdale Brick and Stone Company at Frisco just south of Ellwood City in Beaver County. The clay is of excellent quality and the shale is extensively used in the manufacture of paving brick (see No. 178 and 179, Beaver County).

On Duck and Squaw runs, tributaries coming into the Connoquenessing from the north, clays under the Homewood sandstone and under the Brookville coal have been noted in Report QQ.

On Slippery Rock Creek the heavy Pottsville sandstones continue as the prominent feature and the Vanport limestone is high above the stream. At Rose Point extensive quarrying in this limestone has been carried on and a sample of the shale above it was taken in the quarry. This sample (No. 200) has good plasticity and low green strength. It fires to light to dark red with a firing range from cone 05 to cone 1. It seems suitable for the manufacture of face brick, tile, and sewer pipe. It is easily accessible and is about 15 feet thick.

SUMMARY

It would appear that the Lower Kittanning clay is by far the best clay in Lawrence County and that the shale between it and the Vanport limestone is one of the best and the most accessible of any in the county. The value of the clays in the Pottsville series seems rather doubtful. They were formerly worked but are no longer used. They are probably in most cases too siliceous and not plastic enough. There seem to be no high grade fire clays in the county. Good glacial clays were not seen at any point but there are many sandy glacial clays which are suitable for the manufacture of common red brick and drain tile.

Table 18

Physical tests of Lawrence County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slacking in minutes	Modulus of rupture lbs. per sq. in.	Max. linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested use
180	19.6	3.8	10	117	8.4	6	12	1-6	Buff to dark brown	Face brick
181	21.1	4.3	10	81	6.3	9	18	1-9	Light buff to dark buff	Buff face brick
182	20.8	2.9	7	66	7.6	6	12	1-6	Pale red to brown	Face brick
183	22.8	3.5	6	128	9.8	6	12	1-6	Light red to brown	Face brick
200	19.1	4.0	13	107	6.4	1	11	05-1	Light to dark red	Brick, tile, sewer pipe
220	23.9	3.6	7	194	8.4	02	14	Poor	Red to brown	None
221	22.0	4.2	8	207	7.2	02	15	08-03	Red to brown	Face brick and tile
222	18.3	4.0	7	194	5.5	3	20	03-3	Cream, buff gray	Face brick
223	20.7	4.5	7	153	6.3	1	16	010-02	Salmon, red, brown	Drain tile
226	20.2	4.1	5	135	5.6	1	15	010-02	Red to brown	Drain tile

Table 19

Chemical analyses of Lawrence County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
180	2.28	57.97	2.45	.56	22.50	1.19	1.58	-----	-----	-----	.31	-----
181	7.34	60.11	5.14	.24	24.08	.92	.13	1.19	1.10	.03	.31	.75
182	9.10	60.68	-----	-----	-----	.82	1.83	-----	-----	-----	-----	-----
183	6.89	58.63	10.84	.91	18.95	1.06	2.08	.35	.15	.07	.20	.36
220	-----	56.77	6.29	26.04		-----	-----	-----	-----	-----	-----	-----
221	6.06	55.27	6.35	1.31	21.54	.91	.81	-----	-----	.09	.65	2.59
222	8.58	51.70	6.98	.98	33.10	-----	-----	-----	-----	-----	-----	-----
226	7.50	58.74	7.34	-----	14.55	3.11	1.22	-----	-----	-----	-----	-----
A	-----	64.61	9.98	-----	20.90	.47	1.04	-----	-----	-----	-----	1.93

Localities from which samples were obtained

180. Shale above Vanport limestone, Metropolitan Paving Brick Company, Bessemer
181. White clay, Pearson Brick Company, Volant.
182. Lower shale, Pearson Brick Company, Volant.
183. Shale above Vanport limestone, with some Lower Kittanning clay, Pearson Brick Company, Eastbrook.

- 200. Shale above Vanport limestone, Rose Point.
- 221. Shale from Vanport limestone stripping, New Castle Mining and Clay Products Company, New Castle.
- 222. Clay (Clarion or Scrubgrass), New Castle Mining & Clay Products Company, New Castle.
- 223. Shale from roadside, West Middlesex road, one mile west of New Wilmington.
- 226. Shale on Upper Connoquenessing sandstone, Cascade Park, near New Castle.
- A. Shale above Vanport limestone. Used in portland cement mixture by Crescent Portland Cement Company; analysis from the company and published in Pennsylvania Geol. Survey, 4th ser., Atlas 5, p. 186, 1929.

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WASHINGTON COUNTY.

This county lies north of Greene County and west of Allegheny County. It is bordered on the west by the Panhandle portion of West Virginia and on the north by Beaver County.

It is a plateau upland with an elevation of about 1200 to 1300 feet above sea level, dissected by large streams whose valleys lie 300 to 500 feet below the hilltops, and by an intricate system of smaller tributaries occupying shallower valleys. Very little of the original plateau surface remains. Monongahela River flows along the eastern side of the county in a valley about 700 feet above the sea. This drains the eastern half of the county through Tenmile, Pigeon, Peters and other creeks. The region north of Washington drains into the Ohio through Chartiers Creek, Montour Run, and Raccoon Creek. The western border of the county is drained westward into the Ohio in West Virginia by means of Kings, Harmon, Cross, and Buffalo creeks.

Monongahela River, Chartiers Creek, Raccoon Creek and others of the larger streams have a series of rock terraces along them at an elevation of 900 to 1000 feet above sea level which are covered with sand, clay and gravel. They indicate an earlier stage in stream development, brought to a close during the Wisconsin ice advance when the major streams greatly deepened their valleys. The deposits on the terraces are known as the Carmichaels formation.

The county is crossed from east to west by the Pennsylvania Railroad (P. C. C. & St. L.) through Burgettstown, the Wabash Pittsburgh Terminal Railroad through Hickory, and the Baltimore & Ohio Railroad through Washington. Branches of the Pennsylvania Railroad pass up Chartiers Creek to Washington, follow the west bank of Monongahela River, and extend up Peters and Pigeon Creeks to mining districts. A narrow gauge railroad formerly connecting Washington and Waynesburg was discontinued in 1929.

The bedrock of the county consists of nearly horizontal beds of shale, sandstone, coal, limestone, and unlaminated clay. These include strata ranging in age from middle Conemaugh up through the Monongahela and Washington groups and into the lower portion of the Greene group. In all about 1,400 feet of strata are exposed. Figure 16 gives an idea of the general succession.

Persons interested in the clay resources must also take into account the Carmichaels clay deposited during the Glacial period and now seen on high terraces, and alluvium along the present streams.

CLAY RESOURCES

CONEMAUGH GROUP

All strata below the Pittsburgh coal bed exposed in the county belong to the Conemaugh group and nowhere have the streams cut into this group much deeper than the Ames limestone and the rocks immediately below it. The rocks just below the Ames limestone crop out in the northwestern part of the county on Aunt Clara Fork, on Kings Creek, on Harmon Creek west of Hanlin Station, and on Raccoon

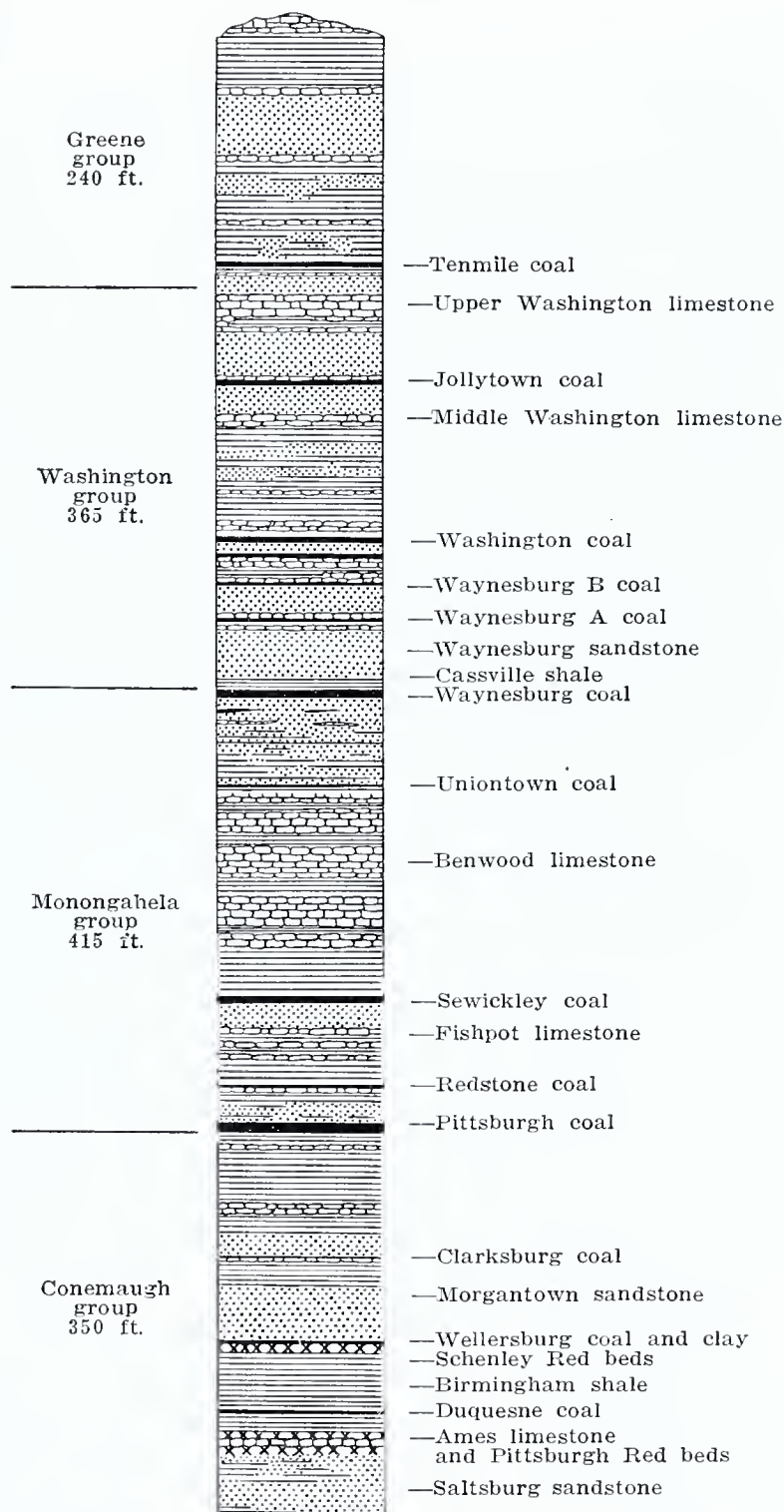


Fig. 16. Section of strata in Washington County.

Creek just south of Murdocksville. These strata may contain un-laminated clay resembling fire clay in appearance but generally too high in lime or limestone nodules to be of much value. No use has been made of them.

The upper portion of the Conemaugh group is more widely exposed. It appears along Raccoon, Little Raccoon, Kings, and Harmon creeks, in Robinson Run valley from McDonald to Midway, and in the Raccoon-Burgettstown district. Farther south it is seen in Cross Creek valley west of Avella, in Chartiers Creek valley from Canonsburg south to Meadowlands, and in the vicinity of Charleroi on the Monongahela.

As seen from Fig. 16, the Conemaugh group contains a few thin limestone and coal beds, some thick sandstones, and a considerable thickness of shale and colored clay, chiefly red. The Schenley red beds are the most valuable for making brick although carefully selected shale beds may be worked. No fire clays of sufficient thickness or purity are known within the county in this group.

Good exposures of the red beds were not noted in the county but no doubt the red beds could be found and opened up. They are excellent material for making brick, as can be seen by the tests on samples 104 and 107 from Allegheny County, where they are used commercially. Shales of good quality appear frequently in the Conemaugh rocks. Shales worthy of attention are present just east of McDonald and their quality is shown by a test made on similar material from Gregg, two miles east of Oakdale (See sample No. 109, Allegheny County).

Half a mile south of Houston, shales are present along the highway and sample No. 113 represents a 10-foot bed of olive shale with a few inches of red shale in the middle of the section. This shale developed a good plasticity, molded to a good, firm body, and burned to light or dark red shades with a burning range of 1000° C. to 1200° C. It could be used in the manufacture of face brick, common brick, and drain tile.

Sample 99 was collected at O'Neil trolley stop one mile south of Charleroi from a cliff of 20 feet of gray shale, reddish toward the base. In the tests this showed similar qualities to No. 113, with fair plasticity. It is suggested that this shale be used in making face brick, sewer pipe, drain tile, or fire proofing.

These tests indicate that good shales occur in the Conemaugh group. The accessibility of the group along the main railroads through Charleroi, McDonald, Burgettstown, and Houston is an added factor in its value.

MONONGAHELA GROUP

The Monongahela group of strata extends from the Pittsburgh coal resting on the Conemaugh group, up to and including the Waynesburg coal. The average thickness is about 400 feet. It outcrops over most of the northern half of the county, and along Monongahela River and its tributaries such as Pigeon Creek. The Pittsburgh coal is mined extensively in this area and it is well to remember that the 400 feet of strata above it constitute the Monongahela group. About one-half of the strata in the group are limestone and this of course limits the available shale and clay. Several thin coal beds above the Pittsburgh coal, and their accompanying black shales are of no value to the brick manufacturer. Thin clays which may be present beneath them are generally impure on account of limy streaks or iron nodules.

The Pittsburgh coal has no fire clay beneath it but does have the same parting between the roof coal and the main bench as occurs in Greene County. This parting is clay or clay shale and ranges from 8 to 20 inches thick. It is very persistent and as it is generally removed during mining operations this clay can readily be obtained. It has been used at Courtney and Manown in the manufacture of fire brick shapes which are not to be subjected to too high a temperature. The material is obtained from near by mines in the form of gob or draw-slate. Sample 101 was collected from an exposure of this parting just west of California. The clay is 10 inches thick and is overlain by 10 inches of roof coal. In the tests it developed good plasticity and showed fair green strength. It had a firing range of 1000° C. to 1350° C. and a fusion point of 1530° C. or cone 20. It would seem to be suitable for low heat duty refractories and for face brick. Although this parting is too thin to be mined by itself, it can be used successfully as a by product in coal mining and more attention should be paid to it.

Immediately above the Pittsburgh coal the strata are variable. There may be 10 to 20 feet of shale overlain by a thin "rider" coal or the interval between the Pittsburgh and the Redstone coals may be chiefly sandstone. West of Florence, the "rider" is absent and heavy sandstone overlies the Pittsburgh coal. In the Bulger district about half of the interval between the Pittsburgh and Redstone coals is gray limestone. In the southeastern part of the county heavy sandstone occupies the interval. In some localities, however, good shale may be found in the interval. In Allegheny County several brick yards are using this shale, notably those at Bridgeville and Wilksburg.

Sample 102 is from a shale bank lying 25 feet above the Pittsburgh coal on Lilly Run just west of California. This shale shows good plasticity and fair green strength. It fires to a light to dark red with a firing range of 1000 to 1200° C. It is well suited for the manufacture of face brick, drain tile and fire proofing. Similar shales occur 2 miles south of California along the railroad. They are 6 to 10 feet thick and are overlain by sandstone and limestone. Buff shale of the same type occurs just west of Meadowlands.

Some of the shale above the Pittsburgh coal is dark colored and very micaceous. This type is exposed near Bamfield, north of Houston. Tests made of this material (No. 114) indicate that it lacks plasticity and green strength and, unless mixed with other more plastic material, would have little value. A thick shale overlies the Pittsburgh coal at the brick yard of the Monongahela Clay Manufacturing Co. at Monongahela. It is not used, however, because of its high carbon content which makes the burning a slow and difficult process.

At this plant the Redstone coal lies 80 feet above the Pittsburgh coal. Above the Redstone coal is a bed of shale about 30 feet thick; this is the material now being used. Sample No. 103 represents an average of this shale. It has good plasticity and high green strength. It fires to a uniform red with a firing range of 1000 to 1150° C. Face brick, drain tile and fire proofing can be made from it. The shale is dug with steam shovels, the accompanying sandstone and limestone are carefully sorted out, and the material trammed to the plant. It is passed through Stevenson dry-pans and molded in a Freese auger machine. The brick are dried in tunnel driers and burned in either round or rectangular down-draft kilns fired with coal. Various types of face

brick, common brick, and back-up tile are manufactured. The plant is situated one mile up Pigeon Creek from Monongahela.

Above this horizon of the Redstone coal and its over-shales little clay or shale is found in the Monongahela group and that which is present is made valueless by its nearness to limestone. Limestone, as before stated, is the dominant rock of the upper portion of the group.

WASHINGTON GROUP

The Washington group includes the strata between the roof of the Waynesburg coal and the top of the Upper Washington limestone. It is the lower portion of the Dunkard series, which is believed to be of Permian age. The Washington group is approximately 300 feet thick and is made up of shale and sandstone with many thin coal and limestone beds. Correlation of the coals and limestones is very difficult and the exact position of a bed within the group is sometimes uncertain.

The group makes the hilltops of much of the area between Washington and the P. C. C. & St. L. Railroad to the north, and covers much greater areas in the southern half of the county.

The city of Washington is underlain by the group and as one follows the Baltimore & Ohio Railroad tracks eastward to the tunnel the strata seen are Upper Washington. The tunnel enters the Upper Washington limestone, passes under a high divide of the Greene group, and emerges into an area of the Washington group. Two brick yards are operating on shales of the Upper Washington horizon, the Donley Brick Company in Washington and the Latrobe Brick Company at Vance, three miles east of the city.

The Donley Brick Company is quarrying a bank near East Maiden Street in Washington which shows the following section :

Section in quarry at Washington

	Feet
Yellow surface soil	3
Yellow weathered shale	7
Limy white-burning layer	2
Soft, blue shale with sandstone concretions	20

At present the whole section is used but the plan of stripping off the upper shales and using only the blue shale is under consideration. Sample 90 represents the mixture of the whole section, eliminating the limy layer and the sandstone concretions. It shows fair plasticity, high green strength, burns to an even light red, and has a burning range of 1000 to 1150° C. It would seem to be suited to the manufacture of face brick and drain tile. The shale is dug with a steam shovel, trammed to the plant and sent through a crusher and dry pans. It is molded in a Freese auger machine, dried in hot air tunnels and burned in coal-fired, down-draft kilns. The product is chimney radius brick and a smaller quantity of common brick. The plant is on the Baltimore & Ohio Railroad, and the products are shipped by rail to New York, Philadelphia and other points.

The Latrobe Brick Company is on the Baltimore & Ohio Railroad at Vance. Their shale bank shows the following section :

<i>Section in quarry at Vance.</i>		Feet
Soil		6
Sandstone		3
Irregular gray shale		10
Concealed		50
Limestone		2
Shale		10

Present workings are on the three upper members, eliminating the sandstone at the shovels. One shovel digs the soil and another the shale, the mixture being made during tramping. The material is trammed to a tippie and carried to the plant below by an aerial tram. The brick are molded in a Freese machine and fired in either coal- or gas-fired kilns. The product is chiefly dark red face brick. These are shipped by rail to New York, Boston, Detroit, and other cities. Sample 91 represents the usual mixture. It has good plasticity and very high green strength. It fires red with a firing range of 1000 to 1150° C. In addition to face brick which are now manufactured, drain tile and fire proofing might be made from this shale.

Half a mile north of Lindleys Mills a sample (No. 112) was taken from an exposed cliff. The section showed 6 feet of dark-gray, iron-stained shale overlain by 3 feet of lighter olive-green shale. The sample is a mixture of both. It shows fair plasticity, high green strength, burns to light or dark red, and has a burning range of 1000 to 1200° C. It could be used for making red face brick, fire proofing and drain tile.

These three samples of shales of the Washington group, two in use and the third unused, indicate that the group contains excellent shales for the manufacture of red brick and tile.

GREENE GROUP

The Greene group includes all the strata in the county which lie above the Upper Washington limestone. It occupies the higher ground in the southern part of the county. Only the lower 240 feet of it are exposed in the county. This includes a few thin coals and limestones, but the predominating rock is soft, thinly laminated, buff shale. A seemingly inexhaustible supply of this shale suitable for making brick is evidenced in the road cuts throughout southern Washington County.

Sample 111 represents this shale as exposed along the road near Prosperity. Similar shale is common between this point and Lindleys Mills. The tests show that the plasticity is somewhat low, its green strength fair. It fires to light or brownish red with a firing range of 1000 to 1200° C. It could be used for common brick but a better product could be made by including with it some of the yellow soil or clay common over the surface of that region. This would add greatly to its plasticity and green strength.

CARMICHAELS FORMATION

This includes the unconsolidated sandy, clay and gravel deposits resting on elevated rock shelves or terraces along the major streams of the county. The rock shelves are believed to be remnants of pre-Glacial stream channels which stood about 200 feet higher than the present major streams. The Carmichaels deposits were built up in these valleys during an early ice advance of the Glacial Period, perhaps the Illinoian. The deposits, however, are of local origin, not glacial. Terraces of this material appear along Raccoon Creek from its mouth up to and probably beyond Raccoon; on Chartiers Creek up to Meadowlands; and

along Monongahela River and up its tributaries, Pigeon and Tenmile creeks. Along the Monongahela the top of the Carmichaels deposit lies 900 to 1000 feet above sea level, rising up the tributaries to 1020 and 1040 feet. The Carmichaels material is also to be seen in the upper part of the cities of Monongahela, California, and Charleroi, and in large areas southwest of West Brownsville.

The Carmichaels formation is of interest to the clay-worker because of the elay. This may be white plastic elay, yellow and white mottled elay, or yellow loamy elay. The origin of the material as river deposit gives it a very irregular distribution as to quantity and quality. It tends to lie in pockety deposits which require careful sampling and prospecting before the deposit can be worked. In former days these soft surface elays were extensively used in southwestern Pennsylvania for making brick, and at New Geneva and Greensboro they were made into stoneware and roofing tile. Our tests indicate that the use of this material was justified as it usually is of high quality. Its pockety distribution has probably been the chief reason for the abandonment of most of the plants using it.

Samples of the Carmichaels elays were collected in Greene and Allegheny counties and described under those county descriptions. Two samples were tested from Washington County localities. The first (No. 100) is from the roadside south of Allenport. It is yellowish plastic clay, part of a series of terraces extending west of the road. It shows high plasticity and very high green strength. It fires to light or dark red and has a firing range of 1000 to 1200° C. It fuses at 1335° C. or cone 12. Red face brick, drain tile, and fire proofing could be made from it. This deposit and other similar ones along Monongahela River are also favored by the presence of the Pittsburgh coal at practically the same level and by excellent shipping facilities.

The other sample was taken north of Hickory on the road to Burgettstown along Burgetts Fork. This road is bordered for a long distance by flat plains of yellowish soil which lie 1000 to 1040 feet above sea level. This soil probably represents the Carmichaels deposit. The clays are widespread and are worthy of attention. The sample tested (No. 110) shows good plasticity and very high green strength, the highest of any of the clays tested in the county. It burns to light to dark red and has a firing range of 1000 to 1200° C. It fuses at cone 14. Prof. Shaw classifies it as very good elay suitable for the manufacture of sewer pipe and paving brick. This places it ahead of most of the elays and shales of the county.

From these tests and those of the neighboring counties it can be seen that the clays of the Carmichaels formation are of unusually good quality and are better than the shales.

Summarizing the elay resources of Washington County we find: A number of good shales occur, well located for development and capable of use in making red brick and tile. These shales have been developed by three firms at Vance, Washington, and Monongahela. No good fire clay occurs in the county except the parting in the Pittsburgh coal, which is suited for the manufacture of low heat duty refractories. The surface clay, especially the Carmichaels clay, is excellent material for making brick and in some cases can be used also in the manufacture of sewer pipe or paving brick. The county is well supplied with gas and coal for fuel in brick plants and with railroad facilities for shipping.

Localities from which samples tested were obtained

90. Bin sample, Donley Brick Company, Washington.
91. Bin sample, Latrobe Brick Company, Vance Station.
99. Shale cliff at O'Neil, one mile south of Charleroi.
100. Terrace clay, Allenport.
101. Clay parting in Pittsburgh coal, just west of California.
102. Shale 25 feet above Pittsburgh coal on Lilly Run, west of California.
103. Average shale from quarry of Monongahela Clay Manufacturing Company, Monongahela City.
110. Light clay terrace soil north of Hickory.
111. Olive shale on road at Prosperity.
112. Shale in cliff half mile north of Lindleys Mills.
113. Roadside cliff of shale half a mile south of Houston.
114. Shale from road quarry north of Houston.

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WESTMORELAND COUNTY

Westmoreland County lies east of Allegheny County, south of Armstrong and Indiana counties, north of Fayette, and west of Cambria and Somerset counties. The western half of the county is an area of rolling hills and deep valleys. The eastern half is crossed, from north to south, by two parallel mountain ridges rising more than 2,000 feet above sea level or about 1,000 feet above the general level of the surrounding country. The eastern ridge forms the eastern border of the county and is known as Laurel Hill or Laurel Ridge. The other is Chestnut Ridge. Both are rugged, rocky, and heavily wooded. Between them lies the low, rolling Ligonier Valley.

The northern, central and eastern parts of the county are drained by the Kiskiminetas-Conemaugh River and its tributaries, Beaver Run and Loyalhanna Creek. The northwestern part of the county drains into Allegheny River. The western and southern parts drain into Youghiogheny River and its main tributaries, Sewickley Creek and Jacobs Creek. One township, Rostraver, lies between the Youghiogheny and Monongahela rivers.

The main line of the Pennsylvania Railroad crosses the county from east to west with many branches extending north and south into the coal fields. The Baltimore & Ohio Railroad follows the east bank of Youghiogheny River, the Ligonier Valley Railroad follows Loyalhanna Valley from Latrobe to Ligonier, and branches of the Pennsylvania follow the Conemaugh-Kiskiminetas River.

The county is crossed by Lincoln Highway and the William Penn Highway, and has an excellent system of connecting roads.

Monongahela River is open to river traffic through a system of locks and the Conemaugh-Kiskiminetas and Youghiogheny rivers will probably be made navigable in the near future. Allegheny River also is navigable.

STRATIGRAPHY

Approximately 2700 feet of sedimentary strata are exposed in the county.

System	Group or Series	Feet
Permian (Dunkard)		300
Pennsylvanian	{ Monongahela	370
	{ Conemaugh	630
	{ Allegheny	280
	{ Pottsville	170
Mississippian	{ Mauch Chunk	140
	{ Pocono	700
Devonian	Catskill-Chemung	110
		2700

Figure 11 gives an approximate idea of the character of these strata.

These beds are gently folded into low anticlines and synclines trending east of north. Chestnut Ridge and Laurel Hill anticlines are much

steeper folds and their axes lie approximately along the crests of the two ridges.

The Devonian rocks are in the center of the two major anticlinal ridges and are exposed only where these ridges are cut by the Conemaugh and Loyalhanna rivers. They contain no clays or shales of special interest.

The Pocono group is practically all sandstone. It outcrops in these same cuts and also in the higher parts of both Chestnut and Laurel ridges. It carries no clays or shales of value.

The Mauch Chunk is made up of red and green shales and sandstones with a limestone (Greenbrier) in the midst of the shales. The shale is high in iron and usually siliceous. Its only use would be for making common brick. It is usually concealed in outcrop on the flanks of the ridges but is well exposed in the Pocono sandstone quarries.

The Pottsville series consists of thick-bedded, coarse sandstone or conglomerate, and in the county it does not seem to contain any beds of clay or shale of importance. It is to be seen in Conemaugh Gap and Packsaddle Gap through the ridges and is partially exposed along Kiskiminetas River between Salina and Apollo.

The Allegheny group carries all the flint clay of the county and almost all of the plastic fire clays. It outcrops along the foot or lower slopes of the two ridges and in the gaps through them; on Conemaugh River above Saltsburg; along Kiskiminetas River from Apollo to the mouth of the river; along Allegheny River from the mouth of the Kiskiminetas south to Valley Camp; on Sewickley Creek near Hunkers; and on Jacobs Creek, west from Tyrone Mills.

The Conemaugh group has the greatest area of outcrop, forming the chief strata in the Ligonier Valley and the surface strata of the western half of the county outside the coal basins. The Conemaugh group may furnish some fire clay or plastic semi-fire clay, especially near the base but it contains mainly shales suitable for the manufacture of building brick.

The Monongahela group and the Dunkard series make up all the strata above and including the Pittsburgh coal. These carry many useful shales and a few plastic clays suitable for face brick manufacture but nothing of better quality. They lie in three synclinal basins; the Irwin basin extending from a point north of Delmont southwest through Irwin, Coulter, Suter, West Newton and Smithton; the Greensburg basin from New Alexandria southwest through Greensburg, the Latrobe basin extending from Blairsville through Latrobe, Mt. Pleasant, to Elverson and Scottdale. A small tract of the Pittsburgh coal and its overlying shales is also present in the Ligonier Valley near Wilpen.

In discussing the distribution and value of the clays it seems best first to describe conditions along the two main thoroughfares, the Kiskiminetas-Conemaugh River, and the main line of the Pennsylvania Railroad. This will be followed by a description of the clays of the main geological divisions of the county as outlined by the anticlinal and synclinal folding.

CLAY RESOURCES

Conemaugh-Kiskiminetas River

This river is considered as one stream here although it is made up of the Kiskiminetas River below Saltsburg and the Conemaugh River above that point. It flows in a deep valley and forms the northern boundary of the county. The Pennsylvania Railroad follows its southern bank entirely across the county and it seems probable that the stream will soon be canalized so that water transportation will be possible from Freeport to Johnstown. With the exception of two short stretches where the stream flows through deep gaps in Laurel and Chestnut ridges and exposes Pottsville, Mississippian, and Devonian strata, the rocks along its banks belong to the Conemaugh and Allegheny groups and are therefore rich in shales and clays, many of which are valuable fire clays.

Where Conemaugh River cuts through Laurel Ridge the arched up beds exposed are: 114 feet of red and green shales and sandstones of the Catskill formation; 700 feet of Pocono sandstones, 144 feet Mauch Chunk red shales, and 100 feet of Pottsville sandstones, all dipping northwest on the west flank of the anticline. No clays are present in these rocks and the shales are sandy. It is unlikely that any of the shale is of value for brick-making.

As these older beds pass below water level to the west, the Allegheny group is brought down to rail level. Just west of Conemaugh Furnace the lowest of these beds, the Brookville coal, carries with it an underclay which may be of value. East of Seward the Lower Kittanning coal is mined in several mines. Although clay is not dug, the usual plastic underclay suitable for making brick or as a plastic bond in fire brick manufacture probably occurs with the coal. This clay and coal lie about 70 feet above the Brookville horizon. Between Seward and New Florence the whole Allegheny group passes below the river. Outcrops are not frequent in this area but it is believed that the clays below the Upper Freeport coal are poor in comparison with those at Bolivar. New Florence is in the center of a syncline and the strata seen belong to the lower half of the Conemaugh group. The Upper Freeport coal is 100 feet below river level. Possibilities here would be the clays near the Brush Creek horizon, the red beds on the higher hills, and a number of shales for making brick. Good fire clays are not to be expected. West of New Florence the strata rise again and the Allegheny group appears east of Lockport. The Upper Freeport coal has been mined east of Lockport and at the village the Lower Kittanning horizon is exposed near water level. Two feet of clay is present immediately below the Upper Freeport coal and the Bolivar clay is 10 or 15 feet below the coal. Other clays are reported below the Lower Freeport, Lower Kittanning, and Clarion (perhaps the Brookville) coals. Some of these, no doubt, could be used in the manufacture of face brick but all seem too impure to be of value as fire clay. At one time a fire brick plant was in operation in Lockport but the clay used was brought from Bolivar, South Fork or elsewhere. Between Lockport and Bolivar, shales only are exposed. Just east of Bolivar the McFeely Brick Company makes buff face brick, from the clay beneath the Lower Kittanning coal which outcrops about 100 feet above the plant. This clay is 9 feet thick and they mine about

6 feet of it. Tests were not made as the clay is similar to that at Robinson, across the river (see Indiana County).

At Bolivar (and at Robinson, Indiana County, across the river) the Pottsville sandstones outcrop along the river below the level of the railroad; from that level upward the whole Allegheny group is exposed in the hills. These strata have yielded an abundance of good fire clay from the Upper Freeport, Bolivar, Lower Kittanning, and Brookville horizons. At the west end of the village the Brookville clay is about 25 feet above the river, the Lower Kittanning 80 feet higher, and the Upper Freeport 230 feet still higher. They are mined at present only on the north side of the river in Indiana County. The section below the Upper Freeport coal is variable but in general it shows a thin clay just under the coal, then a few feet of sandy shale and in places a few feet of limestone, below which is the Bolivar clay. At Bolivar this clay is 11 feet below the coal and averages about 5 feet of excellent flint clay ("hard clay"). This clay contains nodules of iron carbonate, called "iron balls," which have to be sorted out. Where they are too abundant the clay is worthless. The clay ranges from 3 to 12 feet thick, including varying amounts of plastic and flint clay.

Tests of the Bolivar clay made by Shaw (Bull. M 10) indicate that it is a No. 2 flint clay and fuses at cone 29. Analyses of the clay are given below. Nos. 1 and 2 represent the flint clay, No. 3 the plastic. Nos. 1 and 3 are from Report 4H of the Second Geological Survey, No. 2 from Bull. M 10 of the present Survey.

Analyses of Bolivar clay

	1	2	3
SiO ₂	50.84	53.24	59.83
Al ₂ O ₃	30.74	32.85	24.58
Fe ₂ O ₃	3.21	2.61	1.65
TiO ₂	1.26	.86	1.17
CaO	.16	.63	.28
MgO	.28	.82	.87
Alk	.54	.55	3.11
Ign	13.05	8.34	7.83
MnO		.15	
SO ₃		2.86	
P ₂ O ₅		.18	

The clay below the Lower Kittanning coal averages about 10 to 12 feet thick. The upper 2 feet are plastic and of better quality than the remainder but the lower portion is not as sandy as in many localities. Shaw classes the upper clay as a No. 3 fire clay, and 2 samples taken from the lower portion he classes as face brick clays. Clays taken from top, middle and bottom zones all fuse at cone 26. As indicated by the analyses of Bull. M 10 these clays are more siliceous than the Bolivar clay, the silica ranging from 54.99 to 69.92 per cent. The alumina content ranges from 16.83 in the middle or more siliceous layer to 28.45 in the lower portion. These clays are used in the manufacture of common brick.

The lowest clay exposed in the section at Bolivar lies just above a heavy sandstone which is probably the upper sandstone of the Pottsville series. This would make the clay the Brookville clay although it has been described by Shaw as the Mercer. The section at the

mines of the Garfield Fire Brick Company shows 5 feet of plastic clay underlain by 4 feet of sandy shale and this in turn underlain by 8 feet of plastic clay. The upper bench fuses at cone 32 and carries 32.71 per cent alumina. It is classed as a No. 2 fire clay and is used in fire brick manufacture. The lower bench is of about equal rank, its upper half fusing at cone 32 and its lower half at cone 26. The alumina content is respectively 27.65 and 19.96 per cent. Both plants at Bolivar use this clay.

Clay products are not at present made at Bolivar but two plants at Robinson, on the north side of the river are manufacturing fire brick and building brick. These are the Garfield Fire Brick Company and the Joseph Soisson Fire Brick Company. The long and interesting history of Bolivar as a clay working center is fully recorded in Hopkins' report on the Clays and Clay Industries of Pennsylvania. Clay was discovered at Bolivar by James Glover in 1842 or 1843 and the first fire brick were made by him and transported to Pittsburgh on the old Pennsylvania Canal. Robinson & Benny established a plant in 1857; Reese, Hammond and Company were established in 1867; and later the Garfield Fire Clay Company, the Enterprise Manufacturing Company, the Bolivar Brick Company, and the Lincoln Fire Brick and Shape Company were organized. When Hopkins' report was published (1898), the following firms were operating in the district; Reese, Hammond & Company, Garfield Fire Clay Company, Lincoln Fire Brick and Shape Company, James Gardner, Jr. (at Lockport), and David Coulter (a clay mine). Fire brick, paving brick, and building brick were made and clay from Blue Ball and South Fork was used in addition to the local clay. At present the industry is much less active than in the early days and no doubt the best of the clay deposits have been exhausted. However, with careful selection of material, fire brick and building brick may be expected from the district for many years.

Just west of Bolivar and Robinson where Conemaugh River cuts into Chestnut Ridge the strata rise rapidly to the northwest. This rise brings up in rapid succession the Pottsville series 65 feet thick, the Mauch Chunk Series 144 feet thick, and the Pocono sandstones and shales 738 feet thick with some of the upper Devonian shales and sandstones appearing in the center of the anticlinal axis. Nothing of any value in clays or shales is to be found in this stretch, which is called Paeksaddle Gap.

Half a mile east of Torrance, on the west limb of this great antiline, the Allegheny group is exposed along the Pennsylvania Railroad. At least two clays of some thickness are to be seen. The higher of these is a 5- to 7-foot bed of plastic clay below a coal bed $2\frac{1}{2}$ feet thick. This may be the Lower Kittanning coal and clay. The other bed lies approximately 45 feet lower. It is 8 feet thick, the upper half light color, the lower half dark. Over the clay is a coal bed $1\frac{1}{2}$ feet thick. This coal and clay may represent the Brookville. Sample 320 is an average of the entire 8 feet of clay. It has good plasticity and a low green strength. It fires to pinkish buff to gray and has a firing range of 1100 to 1250° C. It fuses at cone 26 and is therefore to be classed as a lowgrade fire clay. No doubt its best use would be in the manufacture of buff face brick.

At Torrance the Upper Freeport coal has been mined. It is under-

lain by some clay up to 5 feet, but this is usually impure and probably of no great value. Nothing of importance is known here at the horizon of the Bolivar clay. Near Strangford and the mouth of Toms Run the Upper Freeport coal 3 feet thick passes beneath the river underlain by a 5-foot clay bed, and a 3-foot limestone.

Thence down the river to Blairsville the exposed rocks are of Conemaugh age. At Blairsville the Morgantown sandstone appears at the level of the river and the surrounding hills carry the shales of the upper Conemaugh. These are of their usual character and are useful mainly in the manufacture of common brick. Conemaugh strata continue to be the surface rocks below Blairsville for 10 miles, with frequent exposures of shale suitable for making brick. Half a mile below Tunnelton, under the influence of the Jacksonville anticline, the Allegheny group is brought up above track level. The Upper Freeport coal is carried up 75 feet above the railroad by this anticline and it and the shales and limestone below it are exposed for about two miles. The horizon of the Bolivar clay here shows about 15 feet of impure clay separated from the coal above by 10 feet of shale and limestone. This clay was used at Tunnelton previous to 1885 for fire brick manufacture but its impurities preclude its present use. Near White's the coal dips down to rail level again and is extensively mined. From that point to Saltsburg the strata are of the lower Conemaugh group. In this area they are unusually sandy, almost the complete section of 230 feet long sandstone. Between the heavy sandstones an occasional shale bed is seen and sample 236 represents such a shale as exposed just south of the Saltsburg bridge. In the tests this smooth, bluish-gray shale shows fair plasticity and green strength and burns to a good red color. It, however, has a short firing range and would be difficult to burn to a good product. No other clays suitable for making brick are seen until the red clays above the upper sandstones in the region are exposed in the higher parts of Saltsburg.

From Saltsburg down the river (which here becomes the Kiskiminetas River) to Edri the Conemaugh strata between the Ames limestone and the Pittsburgh coal are exposed and consist of the ordinary shales of that group. These continue almost to Salina, south of which place the rocks rise toward the Roaring Run anticline where the lower half of the Conemaugh is seen. Sample 321 is a clay exposed along the railroad $\frac{1}{4}$ mile southeast of Salina. The clay is about 6 feet thick under a thin coal. It probably is in the Brush Creek horizon as there is a limestone near by and apparently above it which has the appearance of the Brush Creek limestone. The tests on this sample show fair plasticity and green strength but a narrow firing range of 1100 to 1150° C. It burns to a poor color, light brownish red to dark gray, and fuses at cone 13. It is not a fire clay and does not seem to have much practical value.

At Salina the Upper Freeport coal rises to the surface and has been mined extensively. It is 3 feet 10 inches thick. Beneath it there is 10 to 20 feet of shale and limestone and below that the Bolivar clay 6 to 13 feet thick. This clay is chiefly a flint clay although this varies extremely. The thickness may drop from 13 to 2 feet within a short distance. The deposit of good clay is said to be definitely limited to a small area and drilling outside of this area fails to locate any extension. The deposit is owned by the Kier Fire Brick Company

established there in 1845 and one of the oldest fire brick companies in the State. The mine lies directly under the plant and is reached by a short incline. Sample 189 was taken from the face. It fused at cone 30 and showed a firing range of 1100 to 1350° C. Analysis shows that it carries 51.50 per cent silica, 28.80 per cent alumina, 4.33 per cent iron oxid. Earlier published analyses show a range of SiO_2 from 40.72 to 60.52, Al_2O_3 24.97 to 37.28, and Fe_2O_3 .69 to 2.44. The Kier Fire Brick Company makes a variety of grades of brick, using in some cases their own flint clay alone, in other cases flint clays from Clearfield and Cambria counties. As a bond or sometimes alone they use also plastic clay from the Lower Kittanning bed $1\frac{1}{2}$ miles down the river. The plant is a well-equipped tunnel kiln plant.

Below Salina the strata rise rapidly toward the Roaring Run anticline, the Upper Freeport coal being 835 feet above sea level at Salina and at 1152 feet at Roaring Run on the axis of the fold. Between these points, therefore, the whole of the Allegheny group is brought up with its clays and coals. Between Salina and Roaring Run (Truxall) the Upper Freeport coal has been mined with an average thickness of 4 feet and the Upper Kittanning coal with a thickness of 36 to 42 inches. No clays are worked with these but the Foster No. 5 mine of the Hicks Coal Company, on the Armstrong County side of the river, mines the Lower Kittanning coal and its clay as well as the Upper Kittanning coal. The clay, as usual, has a variable thickness, ranging from a few feet to 15 feet. The greater part of it is somewhat sandy and suitable only for building brick but the portion mined at present is the upper 2 feet which is an excellent plastic clay. This is represented by sample 191 which has good plasticity and fair green strength. It fires to a buff to gray color with a firing range of 1100 to 1250° C. It fuses at cone 20. It is used at Salina for fire brick manufacture and could also be used in making sewer pipe or face brick, in which case more of the bottom clay could be used. No clays thick enough to be of value were seen at the horizon of the Clarion or Brookville coals. Near the Truxall mine of the Kiski Valley Coal Company and near track level a clay appears below what is probably the Clarion coal. This bed shows one foot of white clay and $1\frac{1}{2}$ feet of yellow stony clay. It is probably of no value.

From the axis of the fold at Roaring Run to Apollo the entire Allegheny section is again exposed but no clays of value are known. The Upper Freeport coal reached rail level at Apollo and just east of the city the clay below it is exposed. The Bolivar horizon was once reported as workable here but it seems too impure to be of much value although it does reach a thickness of 5 to 7 feet. In Apollo the Freeport coal is below the surface and the exposed rocks belong to the lower Conemaugh group. A clay is reported 50 feet above the Upper Freeport coal and directly below a thin coal. This may be the same clay seen above Salina and may represent the Brush Creek or a clay in the Mahoning group. At any rate there are usually found between the Brush Creek limestone and the Freeport coal one or more thick beds of clay suited to the manufacture of face brick, sewer pipe and sometimes low grade refractories. These may be present in the vicinity of Apollo.

Between Apollo and Leechburg the Upper Freeport coal is again exposed and beneath it shales and the Lower Freeport and Upper Kit-

tanning coals. The Upper Freeport bed is mined extensively but rarely has any underclay or trace of the Bolivar clay. Just east of Leechburg the following section was seen:

Section east of Leechburg

	Feet
Shale	10
Upper Freeport coal	2
Clay	1
Nodular limestone	7
Clay	2
Sandstone	5
Nodular limestone	3
Sandstone and shale	8

Nearer the station the limestone pinches out and the two clays are separated by one foot of sandstone. If these clays were more regular they would be of value, for a sample (No. 185) taken from a 4-foot bed just under the coal near the station is apparently an excellent clay. It has fair plasticity and low green strength. It burns to dark buff with a range of 1150 to 1300° C. and fuses at cone 30. It seems well suited for the manufacture of refractories, face brick, and sewer pipe. West from Leechburg the Upper Freeport coal remains above the river and has been extensively mined. The condition of the clays beneath it remains about as in the Leechburg area. They are irregular and generally thin and nowhere have they been exploited. This condition continues to the mouth of Kiskiminetas River at Kiskiminetas Junction.

Allegheny River

Allegheny River borders Westmoreland County on the northwest from the mouth of Kiskiminetas River to the mouth of Pucketa Creek at Parnassus. The Pennsylvania Railroad follows the bank of the river along this stretch. From Kiskiminetas Junction south to Garvers Ferry the Upper Freeport coal is high above rail level and the exposed strata are the beds of the upper half of the Allegheny group. Shales are abundant and an occasional thin bed of fire clay is present under the Upper or the Lower Freeport coal but no clay of any great importance is known. One thin bed of clay was seen in this area and sampled as No. 116. This is a light clay 2 feet 4 inches thick half a mile above Garvers Ferry and 30 feet above the railroad. It may be the Lower Freeport clay. It has good plasticity and low green strength. It burns to a cream color with a firing range of 1100 to 1400° C. and fuses at cone 20. It could be used in making face brick and fire proofing.

South from Garvers Ferry the Upper Freeport coal is extensively mined with a thickness of 34 to 42 inches but no clay was noted below it with a thickness of over two feet. The coal is usually overlain by sandstone and underlain by irregular limestones. As the coal dips south and comes closer to river level, the shales of the overlying Cone-maugh group come down to available level and the clays and shales between the Freeport coal and the Brush Creek limestone are exposed, as well as gray shales above the Brush Creek limestone. North of Valley Camp the Valley Camp Brick Company has a brick yard and in their shale pit the following section was seen.

Section in shale pit north of Valley Camp

	Feet	Inches
Buff slabby sandstone	10	
Olive shale	10	
Blue gray shale with marine fossils (sample 215)	20	
Thin gray and brown shales	15	
Coal		9
Shale	1	
Limestone		9
Clay (Sample 216)	5	
Clay with nodular limestone	7	
Concealed	10	
Sandy shale	15	
Upper Freeport coal		

The material used has been chiefly the olive and blue shales near the top of the section. It is probably at the Brush Creek horizon. Sample 215 represents the 20-foot bed of blue-gray shale. From the tests it is seen to have good plasticity and green strength. It fires to a red color with a firing range of 1100 to 1200° C. It might be used in the manufacture of face brick, tile, paving brick, and conduits. Sample 216 is the crumbly clay below the 9-inch bed of fresh-water limestone. This clay is not used. The tests show that it has good plasticity and green strength but that it overfires at 1000° C. and has no great value. This plant has 7 round kilns and fires with coal. The brick are molded with a Freese machine. They have made paving brick, face and common brick.

Through New Kensington and Parnassus the exposed strata are of the lower Conemaugh group with the clays of the Brush Creek horizon the most promising. It is to be remembered that from these clays and shales, the brickyards at Hites, Creighton and Freeport derive their material and that at the latter point the clay is a fire clay. No doubt similar use could be made of these clays and shales between Valley Camp and Parnassus. At Parnassus the beds available are chiefly the lean shales above the Pine Creek limestone and are not as satisfactory as the red beds which should be present 150 feet higher in the hills.

Up Pucketa Creek and in the higher land between it and Kiskiminetas River the Conemaugh group is exposed in an agricultural area. If brick making materials should be desired in that area the red beds above the Ames limestone would be the best material. In the vicinity of Vandergrift Heights olive shales are abundant and sample 117 represents this shale as seen one mile west of Vandergrift on the upper road. This is an average of a 25-foot bank of olive and buff shale. Its plasticity is poor and its green strength fair. It fires to a light red with a firing range of 1000 to 1200° C. It is evidently suited to the manufacture of face brick and fire proofing.

Turtle Creek Valley

From Trafford to Murrys ville, Turtle Creek forms the western boundary of the county while above Murrys ville to the vicinity of Export the stream flows entirely within the county. This valley is served by the Turtle Creek branch of the Pennsylvania Railroad. From Trafford to Murrys ville the exposed strata range from the beds below the

Pine Creek limestone up to the Morgantown sandstone. In this portion of the valley the most valuable clay is the Schenley clay, the red clay just below the Morgantown sandstone. This clay lies about 150 to 175 feet above the railroad. It is the clay used so extensively for red face brick at Blackburn on the Allegheny County side of the valley (see No. 104, Allegheny County). This clay is not developed on the Westmoreland side of the valley. Between the Ames limestone and the Pine Creek limestone the interval is chiefly sandy gray shales of no great value (see No. 105, Allegheny County). These make up most of the exposures along the railroad between Trafford and Murrys ville. Near Murrys ville the Brush Creek limestone rises above the surface and the clays which underlie it are exposed. Elsewhere these have proven of value in making low grade refractories, face brick and other products, and use of them might be possible in Murrys ville. Sample 234 was collected at the foot of the hill just west of Murrys ville and comes from a bed of clay as indicated in the following section.

Section west of Murrys ville

	Feet	Inches
Brush Creek limestone		6
Coal		8
Clay	5	
Sandy shale	5	
Clay, sample No. 234	4	
Sandstone and shale	8	

This clay in the tests shows good plasticity and high green strength. It fires to salmon or light brown color with a firing range of 950 to 1100° C. It seems suited to the manufacture of face brick, hollow tile, conduits, sewer pipe and paving brick.

From Murrys ville to Export the strata are chiefly those of the upper half of the Conemaugh group, of which the red beds of the Schenley horizon are the most promising. These and many shales could be easily worked if brick-making should be undertaken. Between Export, Delmont and Slickville the Pittsburgh coal is mined on a large scale. No clay or shale was noted in connection with it. Two miles north of Murrys ville on Haymakers Run the Upper Freeport coal is brought to the surface for a short distance, by the Murrys ville anticline. The coal is thin and worthless but it is underlain by 3 to 4 feet of plastic clay which on further prospecting may be found to be of value. At present no good outcrops of it are to be seen. This clay must underlie Murrys ville at a depth of not over 100 feet and it or some of the other clays of the Allegheny group might be worked through shafts.

Pennsylvania Railroad Main Line

The main line of the Pennsylvania Railroad in Westmoreland County crosses three important coal-bearing synclines, the Irwin, Greensburg, and Latrobe basins, and it follows deep gaps through the two main anticlines, Chestnut and Laurel ridges. From Trafford to Ardara the shales are between the Pine Creek and Ames limestones of the lower Conemaugh group. These are gray sandy shales of no great value. From Ardara to Irwin the strata are of upper Conemaugh age, including the Schenley red beds, several brick shales, and several pseudo-fire

clays, the latter usually too limey to be of value. Sample 240 represents this clay under the Duquesne coal along the railroad west of Larimer. The tests show good plasticity. It fires to a cream color and should make buff face brick.

Between Irwin and Penn the exposed rocks are the Pittsburgh coal bed and the overlying Monongahela strata of the Irwin syncline. These rocks are mainly sandstones and fresh-water limestones but there are some shales and some of the pseudo-fire clays. The brick plant at Huffs uses material from the horizons above the Pittsburgh coal and no doubt the same shales could be developed along this section of the railroad. East of Penn the strata rise under the influence of the Grapeville anticline and around Jeannette the red beds above and below the Ames limestone should be available. Just east of Jeannette the lower Conemaugh strata are exposed, including thin coals possibly representing the Brush Creek and a Mahoning coal. Sample 233 is one of the pseudo-fire clays below the Mahoning coal along the railroad in the cut east of the station. This clay proves to be suitable for face brick, conduits and hollow tile. It has fair plasticity and green strength; it fires to a salmon color with a firing range of 1000 to 1200° C.

One mile east of Jeannette the Jeannette Brick & Stone Company operates a brickyard manufacturing red face brick, common brick and hollow tile. The quarry on the hill back of the plant is in sandy shale carrying sandstone layers which are eliminated. The quarry bottom is black shale overlying a 1 foot coal which is possibly the Brush Creek coal. The brick are molded with a Freese machine and burned in one round and 3 square kilns. At Oakford Park north of Jeannette the Grapeville anticline brings up the Freeport coal and an underclay. This clay ranges from 2 to 4 feet in thickness. A sample (No. 230) from the mine of R. C. Loughner shows on testing that it is a clay of good plasticity and high green strength. It fires to light buff with a range of 900 to 1100° C. It should be useful in the manufacture of face brick. It fuses at cone 20 and might be used in low heat duty refractory products.

From Jeannette to Radebaugh the strata dip eastward into the Greensburg syncline and just east of Radebaugh a good section of the rocks between the Morgantown sandstone and the Pittsburgh coal are seen. Two samples of clays found here below some of the fresh-water limestones were tested. No. 231 lies 25 feet below the Pittsburgh coal and is 3 feet thick. From the tests it is seen to be a red burning clay high in lime and fusing at cone 8. It seems to be of no value. Sample 232 is from a 3-foot bed of clay 87 feet below the Pittsburgh coal. It has fair plasticity and burns to a poor salmon color with a firing range of 1000 to 1150° C. If the color could be controlled it should make a satisfactory face brick.

From the Radebaugh tunnel to Greensburg and for 3 miles beyond the rocks exposed are the lower half of the Monongahela group, much of which is made up of fresh-water limestones. Clay possibilities around Greensburg are limited to shales in this series and to the clays which accompany the Redstone and Sewickley coals. Just south of Greensburg near Huffs the Keystone Clay Products Company utilizes shale just below the Redstone coal, allowing some of the Redstone clay and some of the surface soil to mix with it. The shale alone is shown

by sample 229 to have good plasticity and fair green strength. It fires red with a firing range of 1000 to 1100° C. It makes face brick of good quality. Below the quarry floor are dark shales overlying the Pittsburgh coal. The plant has 8 round kilns and manufactures red face brick.

Three miles east of Greensburg the Pittsburgh coal rises above the surface again and from that point nearly to Latrobe the strata are of the upper half of the Conemaugh group with the usual shales and red beds available. Through Latrobe the rocks are of the Monongahela group and are not used. At Bradenville the railroad again passes into Conemaugh rocks and continues in them along the west base of Chestnut Ridge to Torrance, through Derry and Hillside. In this section the Pittsburgh coal lies northwest of the railroad and the Upper Freeport coal on the flank of the ridge to the southeast. The condition of this latter coal is not well known because it is usually obscured by terrace gravels and other material from the ridge above. The clays accompanying the Freeport coals are also not known although reports have been made of clays ranging from 1 to 4 feet thick. It is thus seen that from the western border of the county to Torrance there is an abundance of shale and clay fit for making brick but none of higher quality and no good grade of fire clay. East from Torrance the railroad follows Conemaugh River and as already noted frequent exposures of the Allegheny group with valuable fire clays are present, especially in the Bolivar region.

Monongahela and Youghiogheny River Region

The narrow belt of Monongahela strata which forms the Irwin coal basin widens to the south and takes in practically all the county which touches upon these two rivers. The higher hills in this area carry the strata above the Pittsburgh coal while the rivers cut down into the lower Monongahela beds or even down into the upper Conemaugh. Youghiogheny River forms the western border of the county from Coulter to Sutersville. The Baltimore & Ohio Railroad follows the east bank of the river and the Pittsburgh & Lake Erie the west bank. From Coulter to Douglass (or Sutersville) the strata exposed along the railroad are the upper Conemaugh group, the Pittsburgh coal lying some distance above the tracks. Ordinary shales are exposed, with many limestones and an occasional clay bed. At Douglass, on the Allegheny County side of the river clay is exposed near the station beneath a fresh-water limestone. This is sample 283, Allegheny County. Similar clays are present on the Westmoreland side of the river and constitute, with the shales, the only clay materials of that area. At Gratztown the Pittsburgh coal is at river level and the exposed strata are the shales above it. These are well exposed in the quarry of the Yough Clay Manufacturing Company at Gratztown. Several of these beds have been used at the plant but at present the 20-foot bed of clay below the Sewickley coal is the bed in use. This has good plasticity and fair green strength. It fires to a good red and has a firing range of 900 to 1000° C. It is used for the manufacture of red face brick. The plant molds the brick with a Freese machine and burns in either down draft or up draft kilns. The product is a red face brick.

Section at Gratztown

	Feet
Sandstone and soil	10
Dark shale	3
Sewickley coal	1
Clay (No. 284)	20
Sandstone and soil	12
Dark shale	3
Redstone coal	1
Clay and concretionary shale	15
Thin gray shale	6
Sandstone3.....	6
Concealed to railroad	25

From Gratztown to the mouth of Jacobs Creek the rocks are the Monongahela group, including a great deal of the Benwood limestone. The Pittsburgh coal here as elsewhere shows one foot of draw slate which may have a value. A sample of it taken from a stripping pit 3 miles east of West Newton (No. 241) shows that it has very good plasticity, fair green strength, and burns to buff or gray with a pink scum. Its firing range is 900 to 1250° C. and it fuses at cone 32 (3092° F. or 1700° C.). This places it among the high grade fire clays and in a class more refractory than is usual for this Pittsburgh coal parting.

Monongahela River forms the western border of the county in Rostraver Township between Webster and Bellevernon. The rocks exposed along the river are chiefly dark gray shales of the upper Conemaugh group and are of no great interest. The Pittsburgh coal is mined extensively and carries the usual binder of draw slate which may be of value. Between the rivers in Rostraver Township the surface rocks are mainly Monongahela strata or even the higher Permian beds. These may carry some good shales or clays for brick making but are not likely to carry fire clays.

Fayette Anticlinal Area

East of this Irwin-Sutersville area of coal-bearing rocks is an area occupied chiefly by rocks of Conemaugh age. This includes the country around Youngwood, Hunkers, Ruffsedale, and along Jacobs Creek, the southern border of the county. The uplift of the strata is so pronounced that streams have cut through the Conemaugh beds and exposed small areas of the Allegheny group. These areas include a 6-mile stretch along Jacobs Creek, a small tract on Barren Run, and an area near Hunkers. In the vicinity of Hunkers the Upper Freeport coal outcrops along Sewickley Creek from Emmenston to Hunkers and for one mile south on two tributaries, in all an outcrop of 14 miles. Separated from the coal by a few feet of shale, the Bolivar clay has been mined below Hunkers and manufactured into fire brick by the Westmoreland Fire Brick Company. Both flint and plastic clay occur in the bed, the flint clay being very irregular and ranging from 1 to 6 feet. Shaw has reported on two samples of this bed taken from the fire brick company's mine west of Hunkers. The clay included 4 feet of semi-flint and 4 feet of plastic clay, separated from the coal by 3 feet of limestone and 10 feet of sandstone. The harder clay fuses at cone 26 to 30 and is classed by Shaw as No. 2 and No. 3 clay.

The anticline brings up the entire Allegheny group along Jacobs Creek between Tyrone Mills and the mouth of Barren Run but the exposures are poor. Some mining was done on the Bolivar bed in this area in earlier days and the Connellsville folio reports it as a 12-foot bed on the east side of Meadow Run half a mile from its mouth or about one mile north of Tyrone Mills. The Jacobs Creek area has no railroad or good highway. When these come the Bolivar clay and perhaps lower clays in the Allegheny group may be developed. Aside from these areas of Allegheny clays the region is one of lower Conemaugh rocks in which there are abundant shales for making brick. Half a mile north of Youngwood, a cliff of 15 feet of slaty, gray shale was sampled (No. 228) and test shows good plasticity and high green strength. It fires red with a range of 900 to 1100° C. From it, face brick, hollow tile and conduits could be manufactured.

Latrobe-Uniontown Basin

The next region to the east is a syncline which carries the Pittsburgh coal and the overlying Monongahela group. This is a broad area devoted largely to coal mining and including such mining towns as Scottdale, Alverton, Mt. Pleasant, Hecla, Klondike, and Hostetter. The clays of this region include the draw slate of the Pittsburgh coal, the clays of the Redstone and Sewickley coal horizons and numerous shales above the Pittsburgh coal. Development of these materials has not been undertaken.

Chestnut Ridge

East of the Latrobe coal basin the strata rise toward the Chestnut Ridge anticline. This ridge crosses the county from Acme to Bolivar. The clay possibilities along Conemaugh River have been discussed. South from Packsaddle Gap the only clay resources of much value are the Allegheny strata which flank the ridge both sides. Usually these rocks appear on the lower slopes of the ridge but in the vicinity of Derry they extend over the crest. The wooded condition and the abundance of sandstone blocks on the lower slopes obscure the outcrops and little is known of them from Torrance to Loyalhanna Creek. Freeport coal can be seen at Kingston and near Long Bridge at either end of Loyalhanna Gap. At Kingston the Joseph Soisson Fire Brick Company operates a brick yard for the manufacture of low heat duty refractories and paving brick, face brick, brattice block, etc.

Section in quarry at Kingston

	Feet
Soil	-
Coal blossom	-
Shale	5
Micaceous sandstone	2
Shale	5
Coal	1
Soft fire clay	1
Semi-flint clay (sample 239)	10
Soft clay	4
Heavy sandstone	10

Tests by Shaw on a sample collected here for an earlier report show

that the harder clay fuses at cone 20 and that it contains 60.07 per cent SiO_2 and but 14.64 per cent Al_2O_3 with 9.84 per cent Fe_2O_3 . Tests made from sample 239 collected by the author show it to have good plasticity and fair green strength. It fires to a cream to gray color with a firing range of 1000 to 1200° C. It fuses at cone 18, and is well adapted to the manufacture of buff face brick. This clay is below the Upper Freeport horizon and may represent the Brookville coal. The author does not believe that it is the Sharon clay as stated in Bulletin M 10. Other exposures in Loyalhanna Gap are obscured but no doubt this and other clays of the Allegheny group may be expected.

South from Loyalhanna Creek along the Chestnut Ridge little is seen of the clay-bearing strata. The Upper Freeport coal is occasionally seen and was formerly mined, and there is a possibility of uncovering the Bolivar, Lower Kittanning, and Brookville clays on the slopes of the ridge. The use of the clays of the Allegheny group to the south in Fayette County gives added hope that further prospecting may bring them to light.

Ligonier Valley

The region between Chestnut and Laurel ridges is chiefly underlain with Conemaugh strata which include shales for making brick. Near Wilpen there is a small area of Pittsburgh coal and its accompanying shales. The better clays of the valley are to be expected in the Allegheny group which outcrops on the flanks of Chestnut Ridge and Laurel Ridge. A cross section of the valley between Seward and Bolivar has been described. The Bolivar clay is present north from Ligonier to Bolivar on the flank of Chestnut Ridge but is subject to "annoying variations." On the flank of Laurel Ridge it is not known to be of value. It is seldom seen south of Ligonier. The Lower Kittanning coal is said to be underlain by 5 to 7 feet of plastic clay under which is a distinctive hard grit with matted stems. Future prospecting may develop this plastic bed or may disclose clay at the Brookville horizon. The country is agricultural and no development of clay has been made outside of the Bolivar region. The Ligonier Valley Railroad serves the valley.

With the irregular condition of the fire clays of the county, especially of the clays below the Upper Freeport coal, and with the obscured character of the beds along the mountain sides it seems impossible to make any estimate of the clay resources in tonnage figures. It can be noted, however, that the fire clays are practically confined to the Allegheny group and that shales and clays for brick-making are abundant in the rocks of the Allegheny and Conemaugh groups.

Table 22

Physical tests of Westmoreland County clays

Sample number	Per cent water of plasticity	Per cent linear drying shrinkage	Time of slaking minutes	Modulus of rupture lbs. per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested uses
34	25.10	-----	6	-----	-----	6	26½	*		No. 3 fire clay
35	23.33	-----	3	-----	-----	11	30	-----		No. 2 fire clay
36	23.10	-----	6	-----	-----	9	20	-----		Paving and coke oven rick
37	24.80	-----	4	-----	-----	9	20	-----		Paving and coke over brick
116	23.8	5.4	11	144	13.2	6	20	07-13	Light cream to buff	Face brick, fire proofing
117	24.9	4.1	4	246	7.9	1	12	07-4	Light red to brown	Face brick, fire proofing
185	21.5	6.2	10	126	6.3	6	30	1-8	Dark buff to gray	Face brick, sewer pipe refractories
189	15.9	.3	4	45	9.2	1	30	02-10	Gray	Refractories
191	19.1	4.1	23	162	6.1	4	20	02-6	Buff to gray	Sewer pipe or face brick
215	22.5	5.5	3.5	200	6.8	05	13	02-4	Red to brown	Face brick, tile conduits, paving brick
216	22.7	5.2	5	200	5.3	02	13	over-fires at 07	Red to brown	None
228	24.2	5.3	6	360	8.1	02	13	010-02	Red to brown	Face brick, conduits, hollow tile
229	22.4	4.5	9	175	6.6	02	14	07-02	Red to brown	Face brick
230	21.5	6.8	6.5	279	3.6	05	20	010-02	Buff to gray	Drain tile
231	-----	-----	-----	-----	-----	-----	8	-----	Red	No value
232	21.2	3.8	-----	-----	5.1	1	10	07-1	Pink to gray-green	Face brick
233	19.6	3.5	6	135	6.3	1	17	07-4	Salmon to gray green	Face brick, conduits, hollow tile
234	43.2	9.2	9	342	6.3	02	16	010-02	Salmon to light brown	Face brick, conduits, sewer pipe, paving brick
236	20.0	3.4	4	112	10.70	1	8	Short	Red to brown	Doubtful value
239	20.0	3.4	7	144	6.2	4	18	07-4	Cream to gray	Face brick
240	22.9	5.9	-----	-----	2.2	05	1	-----	Cream	Face brick
241	23.9	5.7	3	189	4.7	02	32	010-6	Buff to gray	Fire brick
284	20.7	4.3	5.6	154	2.7	02	10	010-07	Light to dark red	Face brick, drain tile
320	18.4	3.4	4	95	7.2	6	26	02-6	Pink buff to gray	Face brick
321	16.2	4.1	3.5	118	3.3	02	13	02-1	Light red to dark gray	None

* Full data on Nos. 34-37 in Bulletin M-10.

Table 23

Chemical analyses of Westmoreland County clays

N ^o .	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃		
37	5.94	60.07	9.84	1.32	14.64	.78	.45	-----	-----	-----	-----	-----		
116	5.84	58.38	3.45	1.76	20.38	1.90	2.39	2.10	1.87	.48	.12	.77		
117	-----	56.79	-----	-----	24.82	1.27	1.75	-----	-----	.18	.69	-----		
185	12.54	52.90	.23	.80	22.69	3.24	1.30	.40	1.49	.21	.56	.61		
189	13.97	51.50	4.33	.88	28.80	1.08	.50	-----	-----	.14	.35	.38		
191	11.22	46.06	6.73	2.46	27.47	.06	1.63	.61	1.03	.05	.06	1.84		
215	8.21	48.22	-----	-----	-----	1.50	-----	-----	-----	-----	-----	-----		
216	7.07	55.63	6.40	.96	26.21	1.12	-----	-----	-----	-----	-----	-----		
228	8.65	49.41	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
229	7.40	57.90	-----	-----	-----	1.75	-----	-----	-----	-----	-----	-----		
230	5.30	55.40	21.23	1.41	8.02	2.70	4.64	.48	1.41	.41	.10	.21		
231	10.47	56.72	8.70	1.17	12.64	4.87	2.12	.84	.80	.07	.23	1.02		
232	10.62	54.26	5.23	1.21	16.54	8.46	1.37	-----	-----	.06	.28	-----		
233	8.03	57.11	23.56	.87	12.24	1.67	-----	-----	-----	-----	-----	-----		
234	6.18	60.22	11.38	1.71	18.18	Tr.	.58	-----	-----	-----	-----	-----		
236	7.09	52.86	6.75	.50	23.86	2.37	3.19	-----	-----	.32	.06	-----		
239	6.13	62.36	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
284	10.36	55.23	6.93	-----	16.12	4.34	1.48	-----	-----	.08	.15	-----		
320	6.50	64.28	5.95	1.12	19.51	.51	.65	.57	1.14	.10	.26	.14		
321	7.95	54.42	8.90	.36	21.22	1.10	2.30	2.01	1.09	.29	.02	.38		
A	12.49	55.68	.83	1.49	29.18	.13	.18	.24		-----	-----	-----		
B	9.12	63.81	1.23	-----	26.39	Tr.	Tr.	-----	-----	-----	-----	-----		
C	13.49	51.92	1.13	1.16	31.64	.03	.44	.40		-----	-----	-----		
D	-----	47.25	.69	1.99	34.35	.58	.09	.26	-----	-----	-----	-----	CO ₂	H ₂ O
E	-----	40.72	2.44	2.28	37.28	.52	.002	.57	-----	-----	-----	-----	.45	13.69
F	-----	60.52	1.65	1.22	24.97	.91	Tr.	.21	-----	-----	-----	-----	.40	15.00
G	-----	55.33	2.91	1.14	27.84	.58	.75	.21	-----	-----	-----	-----	.72	9.39
H	-----	56.78	.32	-----	26.89	.36	.98	3.91	-----	-----	-----	-----	.45	7.49
I	-----	65.37	.75	-----	24.87	.16	.23	3.92	-----	-----	-----	-----	-----	8.38
J	-----	41.75	.65	-----	40.09	.03	1.02	.01	-----	-----	-----	-----	-----	8.79
								-----	-----	-----	-----	-----	-----	13.20

Localities from which samples tested were obtained

34. Bolivar clay, Westmoreland Fire Brick Company, 1 mile west of Hunkers.
Bull. M 10, 1928.
35. Same locality as above. Bull. M 10, 1928.
36. Clay, Kingston Brick Works, Kingston. Bull. M 10, 1928.
37. Hard clay, Kingston Brick Works, Kingston. Bull. M 10, 1928.
116. Lower Freeport clay on railroad ½ mile above Garvers Ferry.
117. Shale along road, 1 mile west of Vandergrift (Vandergrift Heights).
185. Upper Freeport clay, Leechburg.

- 189. Flint clay, Bolivar horizon, Kier Brothers mine, Salina (Armstrong County).
- 191. Lower Kittanning clay, Foster No. 5 mine near Salina (Armstrong County).
- 215. Shale (Brush Creek), Valley Camp Brick Company, Valley Camp.
- 216. Clay under Mahoning limestone, Valley Camp Brick Company, Valley Camp.
- 228. Roadside shale, $\frac{1}{2}$ mile north of Youngwood.
- 229. Shale below Redstone coal, Keystone Clay Products Company, Huffs.
- 230. Upper Freeport clay, Oakford Park, north of Jeannette.
- 231. Clay, 25 feet below Pittsburgh coal, east of Radebaugh on Pennsylvania Railroad.
- 232. Clay, 87 feet below Pittsburgh coal, east of Radebaugh on Pennsylvania Railroad.
- 233. Clay below Mahoning coal, just east of station at Jeannette.
- 234. Brush Creek clay, on highway just west of Murrys ville (Allegheny County).
- 236. Shale, south of bridge, Saltsburg.
- 239. Clay, Jos. Soisson Fire Brick Company, Kingston.
- 240. Clay under Duquesne coal, west of Larimer along Pennsylvania Railroad.
- 241. Draw slate, in Pittsburgh coal, stripping pit 3 miles east of West Newton.
- 284. Clay under Sewickley coal, Yough Clay Manufacturing Company, Gratz-town.
- 320. Fire clay along Pennsylvania Railroad $\frac{1}{2}$ mile east of Torrance.
- 321. Brush Creek clay, $\frac{1}{4}$ mile south of Salina on Pennsylvania Railroad.
- A. Bolivar clay, Robert Hall, Laughlintown. Second Pa. Geol. Survey, vol. KKK p. 249, 1878.
- B. Bolivar clay, King Mine, Reese, Hammond Company, Tub Mill Creek, $\frac{1}{2}$ mile southeast of Bolivar. Hopkins Report p. 81.
- C. Flint clay, Kier Brothers. Salina, Second Pa. Geol. Survey, vol. MM, pp. 259-260, 1879.
- D. Flint clay (top portion), Kier Brothers, Salina. *ibid.*
- E. Flint clay (middle portion), Kier Brothers, Salina. *ibid.*
- F. Flint clay (bottom portion), Kier Brothers, Salina. *ibid.*
- G. Plastic clay, Kier Brothers, Salina. *ibid.*
- H. Plastic "furnace clay," Jacobs Creek. *ibid.*
- I. Flint "forge clay," Jacobs Creek. *ibid.*
- J. Clay, Westmoreland Fire Brick Company, Hunkers. Hopkins Report, p. 173.

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U. S. Geol. Survey Geol. Atlas, Latrobe folio (No. 110), 1904.
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KEY TO LOCATIONS OF ALL SOUTHWEST PENNSYLVANIA SAMPLES, BY NUMBER

(For detailed locations see county descriptions; for map location see Pl. 1.)

No.

82. Mixed shale, The Brick and Stone Co., Waynes-
burgGreene County
83. Shale along road 3 miles north of SpraggsGreene County
84. Blue shale along road 3 miles south of Waynes-
burgGreene County
85. Underclay along road east of RutanGreene County
86. Terrace clay along road west of Rices Landing ..Greene County
87. Terrace clay 3 miles west of Rices LandingGreene County
88. Olive shale along road 2 miles south of Cummins ..Greene County
89. Red shale in village of New FreeportGreene County
90. Mixture of shales, Donley Brick Co., Washington, Washington County
91. Mixture of shales, Latrobe Brick Co., Vance Sta. ..Washington County
92. Clay at east end of bridge, Point MarionFayette County
93. Shale along road, southwest border of Point
MarionFayette County
94. Terrace clay from pit southeast of New Geneva ..Fayette County
95. Shale along railroad north of New GenevaFayette County
96. Olive shale along railroad north of Masontown
bridgeFayette County
97. Underclay 0.6 mile south of MoyerFayette County
98. Upper shales, Soisson shale pit, MoyerFayette County
99. Shale along road 1 mile south of Charleroi at
O'NeilsWashington County
100. Terrace clay, AllenportWashington County
101. Clay parting in Pittsburgh coal, west of Cali-
forniaWashington County
102. Shale 25 feet above Pittsburgh coal on Lilly Run..Washington County
103. Shale above Redstone coal, Monongahela Clay Mfg.
Co., Monongahela CityWashington County
104. Red clay shale, Wynn Brick Co., BlackburnAllegheny County
105. Shale near base of section, Wynn Brick Co., Black-
burnAllegheny County
106. Clay below Ames limestone, Van Ormer Brick Co.,
PitcairnAllegheny County
107. Upper shales, Van Ormer Brick Co.Allegheny County
108. Shale, Walkers Mills Stone and Brick Co., Walkers
MillsAllegheny County
109. Olive shale, along road 2 miles east of Oakdale ..Allegheny County
110. Terrace clay along road north of HickoryWashington County
111. Olive shale along road, ProsperityWashington County
112. Shale along road ½ mile north of Lindleys Mills, Washington County
113. Shale along road ½ mile south of HoustonWashington County
114. Shale from roadside quarry north of HoustonWashington County
115. Shale from F. C. Mayer Co. pit, BridgevilleAllegheny County
116. Underclay from river cliff opposite FreeportWestmoreland County
117. Shale along road 1.3 miles west of Vandergrift ..Westmoreland County

- No.
126. Red shale above Ames limestone, 2 miles north of
IndianaIndiana County
 127. Underclay opposite AmbridgeBeaver County
 128. Clay under Brush Creek limestone opposite Se-
wickleyAllegheny County
 129. Shale above Pine Creek limestone, WittmerAllegheny County
 130. Shale below Pine Creek limestone, WittmerAllegheny County
 131. Shale above Pine Creek limestone, Powers Run,
BlawnoxAllegheny County
 132. Shale above Pine Creek limestone, old quarry,
HarmarvilleAllegheny County
 133. Shale above Pittsburgh coal, Milliken Brick Co.,
WilkinsburgAllegheny County
 134. Ground shale mixture, Milliken Brick Co., Wilkins-
burgAllegheny County
 135. Clay from bank of John Ward & Sons, Pittsburgh, Allegheny County
 136. Upper shales, Hooper Bros. pit, PittsburghAllegheny County
 137. Purplish lower clays, Hooper Bros. pit, Pittsburgh, Allegheny County
 138. Ground mixture, Gough Brick and Tile Co., Pitts-
burghAllegheny County
 139. Upper shale, Gough Brick and Tile Co., Pittsburgh, Allegheny County
 140. Lower clay, James Fox pit, West End, Pittsburgh, Allegheny County
 145. Red shale, Iron City Brick and Stone Co., Pitts-
burghAllegheny County
 146. Buff shale, Entress Brick Co., PittsburghAllegheny County
 147. Ground mixture, Booth & Flinn yard, Pittsburgh, Allegheny County
 148. Upper shales, Sankey Bros. yard, PittsburghAllegheny County
 149. Lower shales, Sankey Bros. yard, PittsburghAllegheny County
 150. Lower shales, M. Lanz Brick and Tile Co., Pitts-
burghAllegheny County
 151. Ground mixture, Martin Brick and Paving Co.,
HitesAllegheny County
 152. Shale, McFetridge Bros. Brick Co., CreightonAllegheny County
 153. Underclay, Natrona HeightsAllegheny County
 154. Underclay along railroad, Allison Park Sta.Allegheny County
 155. Underclay, Gourdhead Run, near Allison Park ...Allegheny County
 156. Underclay, TalleycaveyAllegheny County
 157. Underclay under high bridge, EmsworthAllegheny County
 158. Semi-flint clay along road opposite AmbridgeBeaver County
 159. Fire clay, Willard Brick Co., KittanningArmstrong County
 160. Fire clay, Upper Kittanning Brick Co., Bradys
BendArmstrong County
 163. Shale, A. Q. Starr Brick Co., MarsButler County
 164. Clay, Martin Brick Co., CalleryButler County
 165. Clay, along road south of ConwayBeaver County
 166. Clay, Pennsylvania Clay Co., ConwayBeaver County
 167. Clay, Rochester Clay Products Co., RochesterBeaver County
 168. Shale, Rochester Clay Products Co., Rochester ...Beaver County
 169. Shale, near Haney lumber yard, RochesterBeaver County
 170. Clay, Westmoreland Brick Co., New BrightonBeaver County
 171. Terrace clay, Elverson Pottery, New Brighton ...Beaver County
 172. Clay, The Fiske Co., DarlingtonBeaver County
 173. Clay, stripping pit of Darlington Fireproofing Co., Beaver County

- No.
174. Shale, Beaver Clay Mfg. Co., New Galilee,Beaver County
175. Clay, Beaver Clay Mfg. Co., New GalileeBeaver County
176. Shale, Pittsburgh Clay Products Co., EastvaleBeaver County
177. Fire clay, McLain Fire Brick Co., MerrillBeaver County
178. Fire clay, Clydesdale Brick and Stone Co., Frisco, Beaver County
179. Shale, Clydesdale Brick and Stone Co., FriscoBeaver County
180. Shale, Metropolitan Paving Brick Co., Bessemer ..Lawrence County
181. Upper white shale and clay, Pearson Brick Co.,
VolantLawrence County
182. Lower shales, Pearson Brick Co., VolantLawrence County
183. Shale, Pearson Brick Co., EastbrookLawrence County
185. Fire clay, west end of bridge, LeechburgWestmoreland County
186. Shale along road south of Cooks Summit.....Armstrong County
187. Clay, 5 miles east of Kittanning on the Sagamore
RoadArmstrong County
188. Flint clay, on Kittanning-New Bethlehem road just
north of junction with the Sagamore RoadArmstrong County
189. Flint clay, Kier Fire Brick Co. mine, SalinaArmstrong County
190. Fire clay, Freeport Brick Co., FreeportButler Co.
191. Fire clay, Foster No. 5 mine, Hicks Coal Co., near
SalinaWestmoreland County
192. Fire clay, Harbison-Walker mine, Templeton.....Armstrong County
193. Flint clay, McLain Fire Brick Co., St. Charles ...Armstrong County
194. Fire clay, Graf-Kittanning Co., CraigsvilleArmstrong County
196. Fire clay, Pa. Ceramic Clay Products Co., West
WinfieldButler County
197. Shale mixture, J. B. Coen Brick and Tile Co., West
HomesteadAllegheny County
198. Clay, J. B. Coen Brick and Tile Co., West Home-
steadAllegheny County
199. Shale, on B. & O. R. R. west of ZelienopleButler County
200. Shale above Vanport limestone, Rose PointLawrence County
201. Clay, Keystone Collieries Co., IsleButler County
202. Shale, near east end of Main St. bridge, Butler ..Butler County
203. Shale, along Rochester road, 2 miles west of
ZelienopleButler County
215. Shale, Valley Camp Brick Co., Valley CampWestmoreland County
216. Underclay, Valley Camp Brick Co., Valley Camp ..Westmoreland County
217. Red clay, in city of ClairtonAllegheny County
218. Shale, 1 mile north of Monongahela City on east
side of riverAllegheny County
219. Shale, east side of river at ClairtonAllegheny County
220. Shale, at county line west of Slippery RockLawrence County
221. Shale mixture, New Castle Mining and Clay Prod-
ucts Co., New CastleLawrence County
222. Fire clay, New Castle Mining and Clay Products
Co., New CastleLawrence County
223. Shale, just west of New WilmingtonLawrence County
225. Shale, on B. R. & P. Ry. west of Harrisville Sta., Butler County
226. Shale, Cascade Park, New CastleLawrence County
227. Red shale, (Mauch Chunk), west slope of Chest-
nut RidgeFayette County
228. Shale, ½ mile north of YoungwoodWestmoreland County
229. Shale, Keystone Clay Products Co., HuffWestmoreland County

- No.
230. Fire clay, Loughner mine, Oakford Park Westmoreland County
231. Clay, 20 feet below Pittsburgh coal, Radebaugh tunnel Westmoreland County
232. Clay, 70 feet below Pittsburgh coal, Radebaugh tunnel Westmoreland County
233. Clay, in railroad cut just east of Jeannette Westmoreland County
234. Clay, below Brush Creek coal, $\frac{1}{2}$ mile west of Murrys ville Allegheny County
235. Shale over Woods Run limestone, near Abers Creek, west of Murrys ville Allegheny County
236. Blue shale, under Saltsburg sandstone, Saltsburg .. Westmoreland County
237. Clay, below Ames limestone, $4\frac{1}{2}$ miles northeast of Saltsburg on Indiana road Indiana County
238. Shale, $2\frac{1}{2}$ miles northeast of Indiana, on Clymer road Indiana County
239. Fire clay, Kingston Brick Works, Kingston Westmoreland County
240. Clay, in railroad cut, Larimer Westmoreland County
241. Parting clay, in Pittsburgh coal, 3 miles east of West Newton Westmoreland County
283. Clay in railroad cut, Douglass Sta. Allegheny County
284. Clay, Yough Clay Co., Gratztown Allegheny County
320. Fire clay, $\frac{1}{2}$ mile east of Torrance on railroad ... Westmoreland County
321. Clay, on railroad $\frac{1}{2}$ mile east of Salina Westmoreland County
- 331A. Fire clay, Hubbard mine, Versailles Allegheny County
- 331B. Fire clay, Hubbard mine, Versailles Allegheny County
- 331C. Fire clay, Hubbard mine, Versailles..... Allegheny County
358. Catskill red shale, 1 mile east of Indiana Co. line, Conemaugh Gap Cambria County
376. Shale, $\frac{1}{2}$ mile north of Wehrum Indiana County
377. Wehrum clay, south of Dilltown Indiana County
381. Clay, 3 miles north of Bruin, along road Butler County
382. Shale, 3 miles north of Bruin, along road Butler County
390. Shale, along road just north of Oneida Sta. Butler County

Table 24

Physical tests of Southwest Pennsylvania clays and shales

Sample number	Water of plasticity % of dry weight	Shrinkage water % of dry weight	Pore water % of dry weight	Time of slacking in minutes	Drying shrinkage % of dry volume	Drying shrinkage % of dry length	Fusion*			Modulus of rupture lbs. per sq. in.	
							Cone	Degree F.	Degree C.	Neat	Sand- clay 50-50
82	23.2	7.8	15.4	6	14.5	5.1	11	2417	1325	366	186
83	25.0	10.4	14.6	5	20.6	7.4	13	2462	1350	429	195
84	21.9			3		3.3	9	2345	1285	80	
85	25.8	12.6	13.2	5	24.8	9.0	10	2381	1305	419	123
86	23.0	10.6	17.4	8	18.2	6.4	14	2552	1400	282	87
87	24.0	9.2	14.8		17.1	6.6	14	2552	1400		
88	27.6	9.8	17.8	5	17.3	6.1	12	2435	1335	281	135
89	25.2	12.4	12.8	7	23.2	8.4	13	2462	1350	324	131
90	22.6	9.5	13.1	6	18.2	6.5	9	2345	1285	381	
91	25.2	11.0	14.2	8	20.4	7.3	8	2300	1260	530	
92	27.6	14.4	13.2	5	26.0	9.5	13	2462	1350	243	108
93	25.4	13.6	11.8	3	25.8	9.5	11	2417	1325	306	
94	32.2	12.6	19.6	9	21.8	7.6	17	2687	1475	351	140
95	25.8	10.7	15.1	4	19.8	7.1	7	2282	1250	160	117

Table 24

Physical tests of Southwest Pennsylvania clays and shales—Continued

Sample number	Water of plasticity % of dry weight	Shrinkage water % of dry weight	Pore water % of dry weight	Time of slacking in minutes	Drying shrinkage % of dry volume	Drying shrinkage % of dry length	Fusion*			Modulus of rupture lbs. per sq. in.	
							Cone	Degree F.	Degree C.	Neat	Sand- clay 50-50
96	26.1	6.9	19.2	5	12.4	4.5	7	2282	1250	140	
97	22.6	7.8	14.9	3	14.8	5.1	13	2462	1350	162	126
98	26.0	8.8	17.2	5	15.7	5.5	11	2417	1325	145	134
99	28.6	12.4	16.2	4	22.4	8.1	13	2462	1350	261	134
100	33.5	19.3	14.2	120	35.0	13.2	12	2435	1335	324	261
101	23.1	13.3	19.8	4	24.6	9.1	20	2786	1530	288	99
102	25.6	8.9	16.7	4	16.2	5.6	11	2417	1325	259	131
103	26.0	14.1	11.9	5	27.0	10.0	6	2246	1230	391	202
104	27.4	12.1	15.3	4	22.9	8.3	13	2462	1350	319	135
105	19.8	3.2	16.7	4	5.8	1.9	11	2417	1325	72	41
106	22.1	6.7	15.4	6	12.6	4.4	5	2201	1205	208	107
107	25.8	12.1	13.7	5	23.3	8.5	11	2417	1325	424	176
108	28.4	11.8	16.6	7	21.9	8.0	15	2615	1435	326	191
109	24.3	5.4	18.9	5	10.0	3.3	12	2435	1335	270	
110	33.2	15.1	18.1	11	26.8	9.9	14	2552	1400	632	246
111	26.5	10.1	16.4	6	18.1	6.4	12	2435	1335	248	168
112	29.1	12.9	16.2	6	23.7	8.6	7	2282	1250	450	135
113	26.7	9.9	16.8	6	17.9	6.4	14	2552	1400	306	133
114	27.4	4.1	23.3	4	6.6	2.4	10	2381	1305	45	42
115	18.7	4.7	14.0	4	8.1	2.9	12	2435	1335	207	129
116	23.8	8.4	15.4	11	15.1	5.4	20	2786	1530	144	113
117	24.9	6.4	18.5	4	11.5	4.1	12	2435	1335	246	90
126	23.6	8.5	15.1	7	16.4	6.0	12	2435	1335	322	118
127	22.7	8.9	13.8		17.2	6.3	16	2669	1465		
128	24.7	9.1	15.6		16.9	6.0	7	2282	1250		
129	23.7	4.5	19.2	4	8.0	2.8	13	2462	1350	86	45
130	25.1	6.5	18.6	4	11.7	4.2	12	2435	1335	121	
131	19.4	4.9	14.5	5	9.6	3.5	13	2462	1350	74	18
132	24.6	7.3	17.3	5	13.8	4.8	7	2282	1250	221	57
133	23.3	6.7	16.5	5	12.2	4.5	12	2435	1335	146	
134	23.6	7.6	16.0	5	13.7	4.9	15	2615	1435	177	100
135	21.9	7.8	14.1	5	14.8	5.4	11	2417	1325	126	98
136	26.3	10.3	16.0	4	18.6	6.8	13	2462	1350	220	104
137	21.1	7.9	13.2	6	15.4	5.6	15	2615	1435	269	103
138	26.3	13.5	12.8	9	26.3	9.6	12	2435	1335	443	292
139	22.3	10.2	12.1	8	19.6	7.1	13	2462	1350	282	108
140	23.8	8.7	15.1	5	17.2	6.3	14	2552	1400	133	20
145	19.2	9.4	9.8	6	19.1	7.0	7	2282	1250		
146	23.5	6.3	17.2	13	11.3	4.1	8	2300	1260		
147	19.3	2.7	16.5	8	4.9	1.6	5	2201	1205		
148	21.4	8.2	13.1	6	15.7	5.6	12	2435	1335		
149	21.3	9.9	11.4	8	20.0	7.2	5	2201	1205		
150	18.6	2.5	16.1	7	4.6	1.6	9	2345	1285		
151	18.4	9.9	8.5	9	19.7	7.2	8	2300	1260		
152	17.4	4.9	12.5	12	9.1	3.2	6	2246	1230		
153	17.7	7.7	10.1	6	15.3	5.4	8	2300	1260		
154	21.2	11.2	10.0	7	17.7	6.0	27	2921	1605		
155	22.8	6.5	16.3	5	12.4	4.5	7	2282	1250		
156	23.2	9.8	13.4	6	18.0	6.6	9	2345	1285		
157	23.9	14.0	9.9	6	27.2	4.3	13	2462	1350		
158	22.1	10.3	11.8	7	19.4	6.9	20	2786	1530		
159	19.3	9.3	10.0	6½	18.7	5.8	20	2786	1530	234	36
160	20.8	10.7	10.1	14	21.3	6.6	26	2903	1595	225	185
163	22.6	6.4	16.1	4	11.9	3.8	13	2462	1350	142	117
164	22.5	7.9	14.6	7	15.2	4.8	12	2435	1335	349	113
165	25.4	10.4	15.0	5	19.7	6.1	20	2786	1530	234	140
166	19.3	6.7	12.6	15	12.9	4.1	16	2669	1465	267	131
167	20.4	8.1	12.3	14	16.0	5.0	20	2786	1530	288	68
168	21.4	9.1	12.3	7½	17.3		15	2615	1435	122	50
169	23.2	7.3	15.9	5	13.8	4.4	13	2462	1350	282	108
170	19.2	7.5	11.7	10	14.7	4.6	23	2894	1590	286	315
171	30.8	16.2	14.6	21	30.0	9.1	14	2552	1400	765	171
172	19.0	2.2	16.8	9	4.1	1.3	20	2786	1530	101	34
173	24.2	11.9	12.3	6	24.3	7.5	13	2462	1350	273	117
174	21.7	4.8	16.9	7	9.0	2.9	12	2435	1335	86	63
175	19.1	5.4	13.7	9	10.4	3.3	20	2786	1530	171	135
176	23.5	5.6	17.9	4½	10.0	3.2	13	2462	1350	151	86

Table 24

Physical tests of Southwest Pennsylvania clays and shales—Concluded

Sample number	Water of plasticity % of dry weight	Shrinkage water % of dry weight	Pore water % of dry weight	Time of slacking in minutes	Drying shrinkage % of dry volume	Drying shrinkage % of dry length	Fusion*			Modulus of rupture lbs. per sq. in.	
							Cone	Degree F.	Degree C.	Neat	Sand- clay 50-50
177	18.4	7.6	10.8	20	15.1	4.8	27	2921	1605	284	135
178	20.4	5.0	15.4	14	9.2	3.2	20	2786	1530	216	162
179	22.2	6.2	16.0	24	11.7	4.0	16	2669	1465	149	93
180	19.6	5.7	13.9	10	11.1	3.8	12	2435	1335	117	61
181	21.1	6.6	14.5	10	12.6	4.3	18	2714	1495	81	63
182	20.8	4.4	16.4	7	8.5	2.9	12	2435	1335	66	46
183	22.8	5.6	17.2	6	10.1	3.5	12	2435	1335	123	88
185	21.5	8.9	12.6	10	17.5	6.2	30	3020	1660	126	135
186	22.1	.1	22.0	18	1.2	.4	12	2435	1335	108	92
187	20.8	3.6	17.2	8	6.8	2.3	27	2921	1605	158	54
188	19.9	3.3	16.6	6	6.4	2.2	29	2984	1640	169	70
189	15.9	.1	15.8	4	.8	.3	30	3020	1660	45	32
190	20.5	6.4	14.1	11	12.6	4.4	26	2903	1595	167	153
191	19.1	6.0	13.1	23	11.7	4.1	20	2786	1530	162	135
192	18.4	.2	18.1	20	4.8	1.6	27	2921	1605	160	74
193	15.5	.1	15.4	10	1.4	.5	30	3020	1660	18	-----
194	19.4	7.7	11.7	12	15.0	5.3	23	2894	1590	111	23
196	19.5	7.2	12.3	15	14.0	4.9	29	2984	1640	124	45
197	19.6	7.0	12.5	6	13.6	4.3	7	2282	1250	270	171
198	20.8	9.1	11.7	5	18.0	5.6	9	2345	1285	77	77
199	21.0	5.4	15.6	7	10.0	3.2	8	2300	1260	135	36
200	19.1	5.0	14.1	13	11.2	4.0	11	2417	1325	107	59
201	16.9	6.1	10.8	12	11.7	3.8	16	2669	1465	86	41
202	21.5	7.5	14.0	12	14.0	4.5	8	2300	1260	77	41
203	20.5	6.8	13.7	15	12.7	4.1	10	2381	1305	54	54
215	22.5	9.1	13.3	3.5	17.5	5.5	13	2462	1350	200	77
216	22.7	8.6	14.1	5	16.6	5.2	13	2462	1350	200	77
217	25.8	5.3	20.4	4.5	17.0	5.4	10	2381	1305	342	149
218	25.8	5.6	20.2	5	14.2	4.5	13½	2491	1375	225	113
219	21.7	9.0	12.6	4	17.7	5.6	12	2435	1335	284	135
220	23.9	6.3	17.6	7	11.1	3.6	14	2552	1400	194	85
221	22.0	5.4	16.6	8	13.2	4.2	15	2615	1435	207	99
222	18.3	6.4	11.9	7	12.5	4.0	20	2786	1530	194	99
223	20.7	7.5	13.2	7	14.1	4.5	16	2669	1465	153	58
225	20.1	6.3	13.8	3.5	11.8	3.8	16	2669	1465	122	45
226	20.2	6.7	13.4	5	12.7	4.1	15	2615	1435	135	35
227	17.8	5.8	12.0	8	11.5	3.7	12	2435	1335	225	94
228	24.2	9.2	15.0	6	16.8	5.3	13	2462	1350	360	149
229	22.4	7.6	14.8	9	14.0	4.5	14	2552	1400	175	72
230	21.5	10.9	10.6	6.5	21.8	6.8	20	2786	1530	279	99
231	-----	-----	-----	-----	-----	-----	8	2300	1260	-----	-----
232	21.2	6.3	14.9	-----	11.8	3.8	10	2381	1305	-----	-----
233	19.6	5.2	14.4	6	10.9	3.5	17	2687	1475	135	58
234	43.2	15.2	28.0	9	30.2	9.2	16	2669	1465	342	135
235	23.7	7.7	16.0	5	14.4	4.6	12½	2448	1343	252	100
236	20.0	5.4	14.5	4	10.5	3.4	8	2300	1260	112	37
237	-----	-----	-----	-----	-----	-----	13	2462	1350	-----	-----
238	25.3	5.5	19.8	7	9.7	3.2	12½	2448	1343	101	54
239	20.0	5.5	14.4	7	10.6	3.4	18	2714	1490	144	63
240	22.9	9.3	13.5	-----	18.0	5.9	1	2110	1150	-----	-----
241	23.9	10.0	13.9	3	18.3	5.7	32	3092	1700	189	100
283	20.6	7.5	13.1	6	14.6	4.6	10	2381	1305	100	40
284	20.7	7.0	13.7	5½	13.4	4.3	10	2381	1305	154	54
320	18.4	5.6	12.8	4	10.6	3.4	26	3002	1650	95	45
321	16.2	6.1	10.1	3½	12.8	4.1	13	2534	1390	118	27
331A	16.3	6.3	10.0	-----	12.6	4.0	20	2786	1530	261	-----
331B	19.9	8.6	11.3	-----	16.8	5.3	20	2786	1530	270	-----
331C	20.6	8.0	12.6	14	15.3	4.8	20	2786	1530	207	-----
353	21.0	8.4	12.6	6	16.5	5.2	15	-----	-----	269	-----
376	22.5	6.2	16.3	5	11.3	3.6	18	-----	-----	198	-----
377	22.9	9.3	13.6	5	17.6	5.5	16	-----	-----	283	-----
381	20.4	3.2	17.2	3	5.7	1.8	27	-----	-----	117	-----
382	23.2	5.1	18.1	5	9.1	2.9	17	-----	-----	113	-----
390	24.7	8.0	16.7	7	14.9	4.7	19	-----	-----	288	-----

*The fusion point of cones varies with the brand and conditions of firing. Prof. Shaw evidently used a different table for translating cone into temperature than that in Table 2.

Table 25

Burning shrinkage of Southwest Pennsylvania clays and shales

Sample number	Linear Burning Shrinkage per cent of dry length.								Volume Burning Shrinkage per cent of dry volume.							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
82	2.3	7.3	2.6	5.4	1.5	-----	-----	-----	6.2	20.3	8.0	15.3	4.8	-----	-----	-----
83	2.9	7.6	7.7	5.8	1.2	-----	-----	-----	8.2	21.3	21.6	16.8	3.5	-----	-----	-----
84	-----	3.0	3.5	7.4	8.3	-----	-----	-----	-1.6	7.5	10.	20.7	23.4	-----	-----	-----
85	5.0	5.6	7.1	7.0	1.5	-----	-----	-----	14.5	16.0	20.1	19.8	-4.3	-----	-----	-----
86	-----	1.0	1.0	3.8	7.0	10.8	6.5	-----	0	2.7	2.7	11.0	19.3	29.4	-18.4	-----
87	1.0	1.5	5.8	4.0	5.5	7.0	6.1	-----	-9	4.9	13.2	11.6	15.6	19.5	-16.5	-----
88	3.9	7.0	6.5	10.5	9.5	5.0	-----	-----	11.2	19.8	17.9	28.5	26.5	14.4	-----	-----
89	5.4	8.2	8.5	5.8	6.5	7.6	2.0	4.6	16.1	23.	23.6	16.5	18.6	21.4	6.0	13.8
90	1.1	2.8	2.7	2.9	1.1	-----	-----	-----	3.9	8.5	8.3	8.8	-1.8	-----	-----	-----
91	2.2	5.5	8.0	6.5	4.0	3	-----	-----	6.9	15.8	22.1	18.1	11.9	1.0	-----	-----
92	4.5	8.0	7.8	8.6	8.6	4.0	-----	-----	13.8	22.2	21.8	24.0	24.1	11.7	-----	-----
93	8.0	7.7	7.8	-4	-2.5	-----	-----	-----	22.3	21.4	21.7	-1.3	-6.9	-----	-----	-----
94	4.1	2.8	2.9	9.6	9.0	4.1	-----	-----	12.1	8.3	8.9	26.6	24.9	11.2	-----	-----
95	2.8	3.5	4.6	7.2	-5	-----	-----	-----	6.5	10.8	13.8	20.3	-1.6	-----	-----	-----
96	1.5	3.5	3.3	6.1	2.9	-----	-----	-----	4.3	11.0	10.5	17.7	8.0	-----	-----	-----
97	1.1	1.3	3.0	5.5	-3	-1.0	-----	-----	3.1	3.6	9.0	16.0	-1.0	-2.9	-----	-----
98	1.5	3.5	2.0	9.1	8.2	7.3	-----	-----	4.5	10.6	5.2	24.1	22.3	20.6	-----	-----
99	1.1	7.5	11.0	9.5	8.5	5.3	-----	-----	3.1	21.0	30.0	26.0	23.0	15.5	-----	-----
100	1.5	3.2	6.0	6.2	8.2	3.0	-----	-----	5.3	9.9	17.1	17.5	22.9	8.9	-----	-----
101	1.8	2.2	4.0	5.6	5.5	6.8	9.2	7.0	5.4	9.9	11.3	16.1	15.7	19.0	25.5	19.3
102	2.2	5.5	9.0	9.0	9.5	5.7	3.1	-----	6.9	15.7	23.8	23.7	26.3	16.3	8.1	-----
103	2.2	2.5	6.5	4.5	-4.1	-----	-----	-----	6.7	7.7	18.2	13.3	-12.	-----	-----	-----
104	3.9	6.5	5.0	4.0	-5	-5.2	-----	-----	12.2	18.1	14.8	12.0	-1.6	-15.	-----	-----
105	1.2	3.5	4.4	11.0	8.5	-----	-----	-----	3.3	10.7	12.3	29.8	23.3	-----	-----	-----
106	-----	2.5	2.1	7.5	-----	-----	-----	-----	-----	7.6	6.8	21.2	-----	-----	-----	-----
107	2.5	5.0	4.9	6.5	6.4	-4.2	-----	-----	4.8	14.1	13.7	18.3	18.2	-12.7	-----	-----
108	2.0	6.1	5.2	8.8	8.9	3.4	-----	-----	5.9	17.2	15.0	24.1	24.2	9.8	-----	-----
109	2.5	4.0	6.1	10.0	6.5	3.5	-----	-----	7.5	11.5	17.3	27.0	18.5	10.5	-----	-----
110	6.7	6.9	9.5	5.9	8.9	5.4	-----	-----	18.7	19.2	26.0	26.9	24.4	15.4	-----	-----
111	2.4	4.1	3.3	7.5	8.6	6.7	-----	-----	6.8	11.8	9.3	20.9	23.3	18.8	-----	-----
112	2.5	7.1	7.0	9.1	6.5	8	1.9	1.2	6.6	19.6	19.4	23.3	18.2	22.1	5.6	3.6
113	1.2	5.9	4.0	5.6	11.6	6.8	-----	-----	2.5	16.6	11.2	15.2	30.1	18.8	-----	-----
114	1.0	-----	5	3.0	8.1	11.8	6.5	-----	2.5	-----	1.7	8.3	22.4	31.2	17.6	-----
115	2.8	5.0	3.7	7.1	1.6	-----	-----	-----	8.0	14.1	10.6	19.5	4.3	-----	-----	-----
116	1.9	1.9	3.4	9.7	9.0	13.2	10.5	5.8	5.9	5.8	10.0	26.3	24.2	34.4	27.9	15.8
117	4.1	7.3	6.7	7.9	7.8	5.5	-----	-----	11.4	19.8	18.1	21.5	21.2	15.1	-----	-----
126	7.0	7.5	10.4	6.7	6.9	7.9	-2.0	-----	19.1	20.3	27.7	18.2	18.8	21.4	-5.7	-----
127	1.4	3.9	4.9	6.4	8.7	7.9	4.9	2.8	3.2	10.8	13.6	17.8	23.4	21.2	13.3	7.7
128	2.7	6.6	8.0	5.6	10.2	-----	-----	-----	7.1	18.1	21.4	15.6	27.2	-----	-----	-----
129	1.0	5.4	11.5	9.5	10.5	-----	-----	-----	2.2	12.0	30.2	25.4	28.0	-----	-----	-----
130	3.2	2.8	4.0	8.4	10.3	5.6	-----	-----	8.7	7.7	11.1	22.8	27.6	15.3	-----	-----
131	-9	2.3	1.7	8.3	7.8	1.4	-----	-----	-2.6	6.1	4.4	22.5	21.2	3.5	-----	-----
132	2.7	7.5	7.8	7.9	7.5	3.2	-----	-----	7.3	20.5	21.2	21.6	20.3	8.8	-----	-----
133	.9	2.8	2.0	8.0	10.1	10.0	-----	-----	1.8	7.4	5.4	21.6	27.0	26.6	-----	-----
134	-1.1	3.4	3.4	7.0	8.2	9.4	-----	-----	-3.1	9.8	9.4	19.2	22.4	25.3	-----	-----
135	2.6	2.2	-----	8.9	1.4	-----	-----	-----	7.0	5.8	-----	23.8	3.4	-----	-----	-----
136	2.8	6.8	5.0	11.3	11.3	3.4	-----	-----	7.9	18.8	13.8	29.8	29.7	10.5	-----	-----
137	1.8	2.8	4.1	3.5	8.8	3.4	-----	-----	4.5	7.8	11.4	9.5	23.8	9.4	-----	-----
138	1.8	3.9	3.6	7.1	4.1	.9	-----	-----	5.4	11.4	10.6	19.9	11.9	2.6	-----	-----
139	.2	3.8	4.5	6.3	7.9	3.2	-----	-----	.6	10.2	12.2	17.2	21.3	8.7	-----	-----
140	-1	2.3	1.9	4.7	7.2	5.8	-5.7	-----	-3	6.0	5.1	13.6	19.8	16.1	-15.8	-----
145	-2.5	1.5	3.6	2.4	3.0	-7.9	-----	-----	-7.3	3.9	10.8	6.3	8.6	-21.7	-----	-----
146	-8	.2	1.2	5.1	6.5	6.0	-3.3	-----	-2.5	0.3	3.8	14.3	18.1	16.7	-9.3	-----
147	2.5	3.0	4.7	6.5	8.3	-7	-----	-----	7.1	8.6	13.1	17.9	22.6	-2.2	-----	-----
148	1.4	1.2	2.7	6.5	7.0	3.0	-2.3	-----	4.3	3.7	8.1	18.2	19.8	8.5	-6.6	-----
149	1.2	2.2	3.2	2.8	1.6	-----	-----	-----	3.1	6.6	9.2	7.9	4.7	-----	-----	-----
150	-1.4	.8	2.1	3.0	9.7	3.2	-----	-----	-4.1	2.2	6.3	8.9	26.4	9.5	-----	-----
151	-2	-4	4.1	6.3	7.2	.4	-----	-----	-1.6	-1.2	11.8	17.7	20.1	1.2	-----	-----
152	.6	1.6	6.4	6.1	7.4	3.0	-----	-----	1.8	5.7	17.9	17.2	20.4	10.8	-----	-----
153	-1.2	1.8	2.0	1.5	.7	1.2	-----	-----	-3.5	5.5	-5.8	4.3	-2.3	-3.1	-----	-----
154	-3	-8	-8	3.3	6.5	5.6	6.0	6.7	-1.0	-2.6	-2.2	9.1	18.2	15.9	17.0	18.5
155	1.4	2.5	4.5	4.8	7.8	-2.1	-----	-----	3.9	7.3	12.8	13.9	21.4	-6.5	-----	-----
156	3.8	4.8	4.7	8.8	4.6	-26.	-----	-----	11.1	14.1	13.8	24.2	13.2	-59.9	-----	-----
157	3.0	4.5	3.9	6.9	3.4	2.0	-7.3	-----	8.5	12.8	10.9	18.9	9.9	5.9	20.4	-----
158	2.5	.6	.7	2.0	2.8	3.2	4.4	5.0	6.9	3.7	4.4	5.7	8.1	9.3	13.4	14.3
159	-1	3.3	3.7	4.2	5.2	4.1	2.3	1.4	-8	10.5	11.5	13.2	16.7	13.0	7.1	4.5
160	.8	-1	-1	1.9	3.1	3.5	3.7	1.4	2.5	-3	.3	6.6	9.6	11.0	11.7	4.3
163	-3	1.8	4.6	5.6	-----	4.1	-----	-----	-1.1	5.4	14.5	18.0	-----	13.1	-----	-----
164	-1.6	.7	3.9	4.7	2.6	-1.	-1.8	-----	-4.9	1.2	12.3	15.1	8.3	-3.3	-5.5	-----
165	.2	1.9	4.1	5.3	6.0	5.2	2.4	.3	.9	5.8	13.1	16.8	19.1	16.7	7.4	1.2
166	-5	0	2.3	3.8	5.1	2.4	-2	-----	-1.6	0	7.1	11.8	16.4	6.5	-5	-----
267	-----	2.7	2.8	3.7	4.4	1.9	-8	-1.2	-----	8.6	8.9	11.6	13.9	5.9	-2.7	-3.8
168	-2.3	-1.3	0	2.5	4.2	3.3	-----	.9	-7.3	-3.9	.2	7.9	13.3	10.3	-----	-----

Table 25

*Burning shrinkage of Southwest Pennsylvania clays and shales—
Concluded*

Sample number	Linear Burning Shrinkage per cent of dry length.								Volume Burning Shrinkage per cent of dry volume.							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
169	.7	3.7	5.6	7.3	6.5	2.4	-.9	-----	2.3	11.6	17.8	23.6	21.0	7.5	-2.9	-----
170	1.4	2.1	3.7	4.1	4.3	2.4	2.1	1.0	4.4	6.5	11.8	12.8	13.7	7.4	6.6	3.3
171	3.8	4.5	8.0	6.2	2.1	.8	-2.3	-----	12.0	14.4	26.1	20.1	6.6	2.0	-7.2	-----
172	1.6	.2	.2	.4	2.1	2.7	3.4	4.1	5.0	.8	.8	1.4	6.6	8.5	10.6	12.8
173	.7	1.4	2.0	4.8	-----	.2	-----	-----	2.3	4.3	6.2	15.3	-----	.6	-----	-----
174	.94	2.1	6.3	6.4	6.2	-3.3	-----	-----	2.8	6.4	20.3	20.7	19.9	-10.4	-----	-----
175	1.5	2.0	3.1	3.8	4.0	4.6	3.5	1.8	4.5	6.3	9.6	12.1	12.7	14.5	11.0	5.6
176	.1	.2	1.4	4.3	6.9	4.0	-----	-----	.5	.8	4.2	13.5	22.2	12.7	-----	-----
177	-.5	0	.3	.8	2.4	.5	-.5	-4.2	-1.8	0	1.1	2.7	7.4	1.8	-1.7	-13.2
178	0	0	.7	1.2	2.9	3.9	5.5	6.5	.2	0	2.2	3.7	8.5	11.3	15.7	18.2
179	.6	1.8	2.7	3.5	5.2	8.1	4.3	3.0	2.0	5.3	8.0	10.2	14.9	22.4	12.4	8.9
180	-.1	.3	0	.7	-----	8.4	-----	-----	-.2	2.5	2.6	2.4	-----	2.4	-----	-----
181	-1.3	-.9	-----	1.0	3.7	4.6	6.3	-----	-3.9	-2.9	0	3.1	10.8	13.3	17.7	-----
182	0	.7	1.0	1.4	4.9	7.6	0	-----	-.2	2.3	3.2	4.1	14.1	21.2	.2	-----
183	-.4	.2	1.4	4.1	7.8	9.8	-----	6.5	-1.1	.5	4.0	11.9	21.7	26.7	-----	18.2
185	-.7	-.6	.4	4.9	5.0	6.3	-----	2.8	-2.2	-1.9	1.2	14.2	14.3	17.8	-----	8.4
186	.1	.6	4.2	5.6	10.9	5.3	-8.5	-----	.2	2.0	12.0	16.0	29.2	15.1	-23.4	-----
187	.9	1.5	3.3	4.9	5.8	7.1	-----	3.6	2.6	4.5	9.8	14.1	16.4	19.7	-----	10.6
188	.2	.7	.8	1.5	2.1	1.6	1.7	.4	.6	2.1	2.4	4.5	6.2	4.9	5.1	1.2
189	5.0	6.4	5.6	9.2	6.3	8.6	7.3	6.8	4.4	18.0	16.0	25.0	17.8	23.7	20.3	19.1
190	-.1	1.8	5.2	4.7	4.8	6.0	1.8	-1.5	-.3	5.5	14.8	13.4	13.6	17.1	5.4	-4.5
191	-.4	2.0	4.9	5.4	6.1	3.0	.5	-.3	-1.2	5.9	13.9	15.3	17.1	8.8	1.6	-.9
192	.2	1.3	2.2	5.6	5.1	5.7	-----	6.4	.6	3.7	6.5	15.8	14.5	16.1	-----	17.9
193	1.2	1.4	4.1	4.8	5.4	4.3	5.1	5.8	3.6	4.1	11.7	13.7	15.4	12.4	14.5	16.4
194	.2	.2	1.8	3.9	4.7	6.2	6.2	2.8	.6	.6	5.2	11.4	13.6	17.7	17.5	8.2
196	-.6	.2	2.3	6.3	5.6	-----	-----	2.0	1.9	.6	6.7	17.8	15.8	-----	-----	-----
197	-.3	.4	4.8	3.7	-----	-----	-----	-----	-1.1	1.4	15.3	-1.1	-----	-----	-----	-----
198	-.1	.7	-1.1	-5.2	-----	-----	-----	-----	-.3	2.1	-3.4	-16.6	-----	-----	-----	-----
199	1.9	4.9	7.6	2.7	-----	-----	-----	-----	5.8	15.7	24.5	8.4	-----	-----	-----	-----
200	.4	2.5	4.7	6.4	-.6	-----	-----	-----	1.4	7.8	14.9	20.5	-2.0	-----	-----	-----
201	1.2	3.0	3.7	1.0	18.1	-----	-----	-----	4.3	8.9	11.3	3.3	-50.5	-----	-----	-----
202	2.6	5.2	7.3	8.4	-7.0	-----	-----	-----	8.3	16.2	22.9	25.3	-22.1	-----	-----	-----
203	3.0	2.0	4.2	4.9	-5.3	-----	-----	-----	8.5	5.6	12.9	15.0	-16.0	-----	-----	-----
215	5.1	6.8	6.6	.6	6.1	-----	-----	-----	16.1	21.8	21.2	2.0	19.5	-----	-----	-----
216	4.3	5.3	5.3	2.7	2.2	-----	-----	-----	13.3	16.8	16.8	8.3	-6.8	-----	-----	-----
217	6.3	7.5	6.1	2.0	1.9	-----	-----	-----	0.9	24.1	19.3	6.1	5.8	-----	-----	-----
218	6.3	7.2	9.1	7.1	6.3	-----	-----	-----	20.2	23.3	29.8	23.0	20.0	-----	-----	-----
219	5.4	5.5	5.0	.1	-----	-----	-----	-----	17.0	17.3	15.7	-.3	-----	-----	-----	-----
220	4.9	6.0	8.4	8.3	5.9	-----	-----	-----	15.3	19.2	27.3	27.0	18.8	-----	-----	-----
221	5.3	4.6	7.2	6.7	3.8	-----	-----	-----	10.3	14.4	23.3	21.5	11.7	-----	-----	-----
222	1.8	2.9	4.3	4.5	5.5	2.8	1.6	-----	5.6	8.8	13.3	14.0	17.3	8.6	4.8	-----
223	1.1	1.9	4.2	6.3	5.3	4.2	-----	-----	3.3	6.0	13.1	20.0	16.9	13.1	-----	-----
225	2.5	3.3	5.7	5.2	2.7	-----	-----	-----	7.7	10.3	18.2	19.8	8.3	-----	-----	-----
226	1.4	1.9	4.0	5.6	4.0	-----	-----	-----	4.3	5.7	12.6	17.7	12.5	-----	-----	-----
227	.9	4.3	5.7	5.7	6.0	-----	-----	-----	2.6	13.3	18.1	18.0	19.2	-----	-----	-----
228	5.0	7.9	8.1	7.3	2.7	-----	-----	-----	15.9	25.7	26.3	23.6	8.5	-----	-----	-----
229	2.6	3.6	6.6	5.9	2.4	-----	-----	-----	7.8	11.3	21.3	18.8	7.3	-----	-----	-----
230	2.5	3.6	3.5	-2.7	-12.	-----	-----	-----	7.7	11.2	10.8	-8.5	-40.7	-----	-----	-----
231	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
232	.7	-----	-----	5.1	-----	-----	-----	-----	2.2	-----	-----	16.1	-----	-----	-----	-----
233	4.0	4.4	5.6	6.3	6.1	2.7	-----	-----	12.5	13.9	17.7	20.0	19.3	8.3	-----	-----
234	4.7	4.9	6.3	5.8	1.5	.3	2.7	-----	14.9	15.6	20.1	18.5	4.5	-1.0	-8.5	-----
235	5.5	7.7	7.3	4.1	4.6	-----	-----	-----	17.5	25.1	23.7	12.7	14.5	-----	-----	-----
236	4.6	4.7	2.4	10.7	-----	-----	-----	-----	14.5	14.7	7.4	-35.7	-----	-----	-----	-----
237	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
238	2.8	4.1	6.3	3.7	1.9	-----	-----	-----	8.9	12.8	20.0	11.6	6.1	-----	-----	-----
239	2.2	3.3	4.8	4.4	6.2	1.7	.2	-----	6.7	10.2	15.1	13.7	19.7	5.2	.8	-----
240	.3	2.2	-----	-----	-----	-----	-----	-----	1.2	6.8	-----	-----	-----	-----	-----	-----
241	.6	5.4	4.7	3.7	3.9	-.8	-----	-----	1.9	17.2	14.9	11.7	12.3	-2.5	-----	-----
283	1.6	4.1	3.9	-----	-----	-----	-----	-----	4.8	12.8	12.3	-----	-----	-----	-----	-----
284	2.4	2.3	2.7	-----	-----	-----	-----	-----	7.5	7.2	8.3	-----	-----	-----	-----	-----
320	.8	.7	2.7	1.9	4.4	7.2	1.4	2.0	2.5	2.2	8.4	5.8	13.8	23.1	4.3	6.1
321	.3	.5	3.3	2.8	-.3	-----	-----	-----	1.1	1.7	10.4	8.7	-1.2	-----	-----	-----
331A	-.3	.5	2.6	2.3	3.6	-3.7	-7.2	-11.7	-1.1	1.7	8.0	7.2	11.3	-11.5	-23.2	-39.6
331B	.4	2.1	4.0	4.4	7.6	-2.7	-1.9	-----	1.2	6.6	12.6	13.8	24.6	-8.4	-5.9	-----
331C	1.3	1.8	4.3	4.6	5.9	-4.5	-2.3	-----	3.9	5.7	13.4	14.6	18.9	-14.2	-7.2	-----
358	2.5	2.4	4.8	6.1	1.7	-1.7	-----	-----	7.6	7.4	15.1	19.5	5.1	-5.3	-----	-----
376	.2	1.8	4.5	6.2	7.4	7.3	7.7	3.6	.8	5.7	14.1	19.7	23.8	23.5	25.0	11.2
377	1.2	4.3	6.7	7.9	7.4	5.7	2.6	.3	3.8	13.5	21.5	25.9	23.8	18.2	7.9	1.1
381	.4	1.4	1.8	2.0	3.3	5.1	6.6	7.3	1.3	4.3	5.4	6.3	10.3	16.2	21.1	23.4
382	.1	1.2	5.2	4.9	7.1	7.6	8.9	3.8	.2	3.6	16.3	15.6	22.8	24.6	29.0	11.7
390	-.3	0.0	1.9	4.2	6.4	8.3	5.5	4.9	-1.1	0.0	5.8	13.2	20.5	27.0	17.3	15.3

Table 26

Porosity and absorption of burned samples of Southwest Pennsylvania clays and shales

Sample number	Porosity percentage of burned volume								Absorption percentage of burned weight							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
82	13.7	9.3	8.9	.7	15.3	-----	-----	-----	12.2	8.5	8.2	.6	13.3	-----	-----	-----
83	22.9	6.1	.3	3.3	11.2	-----	-----	-----	11.8	2.7	.1	1.5	6.1	-----	-----	-----
84	38.2	39.1	44.0	18.9	11.3	-----	-----	-----	24.4	22.6	22.2	9.5	5.5	-----	-----	-----
85	21.0	8.8	4.9	.9	17.5	-----	-----	-----	9.9	4.0	2.2	.5	10.2	-----	-----	-----
86	32.4	30.1	28.2	20.8	11.7	2.2	33.9	-----	19.0	17.1	16.0	10.7	5.7	1.0	23.2	-----
87	30.0	28.8	29.9	24.6	16.0	4.8	34.8	-----	6.8	15.3	14.4	12.1	7.5	2.1	22.6	-----
88	26.8	17.5	12.5	1.4	.5	3.4	-----	-----	4.2	8.3	6.1	.6	.3	1.8	-----	-----
89	21.5	16.2	13.5	9.8	9.7	7.6	16.9	5.9	10.3	7.1	5.9	4.7	4.5	3.4	8.9	2.9
90	28.9	24.4	22.7	26.2	15.6	-----	-----	-----	15.6	12.7	12.2	13.6	9.0	-----	-----	-----
91	27.8	16.9	13.7	4.1	7.5	14.1	-----	-----	14.8	8.2	6.1	1.9	3.8	8.1	-----	-----
92	22.2	13.8	8.9	1.9	3.1	1.0	-----	-----	11.4	6.4	4.2	.9	1.3	5.3	-----	-----
93	13.9	10.0	9.9	4.5	16.8	-----	-----	-----	6.1	4.4	4.3	2.6	12.9	-----	-----	-----
94	23.5	27.0	21.0	.4	.4	13.1	-----	-----	12.8	15.3	11.8	.2	.2	7.1	-----	-----
95	12.5	26.0	25.0	8.8	4.0	-----	-----	-----	6.1	13.8	12.9	4.2	2.5	-----	-----	-----
96	31.0	32.4	32.1	22.6	3.8	-----	-----	-----	1.9	17.5	18.7	11.4	2.1	-----	-----	-----
97	42.0	26.9	24.8	16.5	21.6	30.7	-----	-----	16.6	14.6	12.7	7.8	13.2	22.2	-----	-----
98	31.8	24.6	31.1	35.8	1.5	10.2	-----	-----	18.1	13.1	11.7	15.8	.7	4.8	-----	-----
99	33.0	17.5	8.1	6.1	5.0	7.3	-----	-----	18.8	8.2	3.3	2.6	2.2	3.6	-----	-----
100	29.6	21.7	19.4	7.5	7.1	15.9	-----	-----	16.2	11.3	9.4	3.6	3.2	8.3	-----	-----
101	34.6	28.2	30.8	19.9	12.5	6.0	4.9	4.5	19.5	15.2	16.4	10.0	6.3	2.9	2.2	2.2
102	35.2	25.0	21.1	10.3	5.8	7.1	19.8	-----	19.9	12.3	9.7	4.8	2.6	3.7	11.0	-----
103	24.8	14.0	16.8	.9	25.8	-----	-----	-----	12.9	7.2	7.6	.4	15.9	-----	-----	-----
104	22.8	17.2	1.3	.7	7.6	23.3	-----	-----	11.1	7.9	.5	.3	4.3	14.9	-----	-----
105	35.6	28.4	26.1	10.2	1.2	-----	-----	-----	20.5	15.1	13.7	4.5	.6	-----	-----	-----
106	38.0	33.8	33.2	13.7	-----	-----	-----	-----	21.8	19.3	18.9	6.7	-----	-----	-----	-----
107	27.3	16.0	10.2	1.1	4.0	20.0	-----	-----	14.3	7.6	4.9	.5	1.9	12.3	-----	-----
108	27.4	12.5	21.6	3.8	1.1	12.9	-----	-----	14.7	5.9	10.5	1.7	.5	6.8	-----	-----
109	31.3	25.5	31.0	6.3	3.9	.6	-----	-----	17.8	13.1	15.7	2.6	1.9	.3	-----	-----
110	12.6	16.0	3.7	1.5	.2	15.1	-----	-----	6.1	7.7	1.6	.8	.1	7.6	-----	-----
111	33.1	24.5	25.8	2.3	1.1	14.5	-----	-----	18.7	12.6	13.7	1.1	.5	6.9	-----	-----
112	29.2	16.5	19.9	10.1	8.5	6.6	17.7	13.0	15.9	7.8	9.3	4.5	4.1	3.0	9.8	7.9
113	29.2	18.7	21.9	7.9	6.8	4.8	-----	-----	16.7	9.1	11.4	3.9	2.7	2.3	-----	-----
114	43.2	40.2	42.1	32.8	25.9	18.3	17.9	-----	28.4	25.6	27.8	20.2	13.5	8.5	9.9	-----
115	27.0	27.8	26.6	11.6	10.8	-----	-----	-----	13.9	13.4	13.5	5.3	5.4	-----	-----	-----
116	26.9	18.7	24.3	21.0	10.9	7.4	3.3	12.1	14.9	10.3	12.9	10.6	6.9	3.2	1.5	6.1
117	26.8	18.5	10.0	8.3	10.3	2.9	-----	-----	14.2	8.7	4.8	3.8	2.8	1.4	-----	-----
126	17.3	16.6	10.3	8.8	7.1	6.5	23.1	-----	7.8	6.0	4.2	5.4	3.2	2.8	10.5	-----
127	25.8	19.6	18.0	15.5	9.5	5.1	9.7	9.1	14.0	9.8	8.7	7.2	4.1	2.2	4.7	4.6
128	19.4	38.9	9.9	8.2	3.1	-----	-----	-----	10.3	18.4	4.5	4.0	2.2	-----	-----	-----
129	33.2	24.1	11.6	4.4	.9	-----	-----	-----	19.2	12.8	4.9	1.9	.4	-----	-----	-----
130	21.2	28.1	26.3	3.5	.6	3.7	-----	-----	11.6	15.5	14.4	1.6	.2	1.9	-----	-----
131	32.2	26.3	24.1	10.8	1.0	6.6	-----	-----	18.2	13.5	12.7	4.6	.4	3.5	-----	-----
132	30.4	16.2	6.8	4.5	10.9	13.3	-----	-----	15.8	7.3	3.0	2.0	4.9	6.9	-----	-----
133	30.0	31.6	29.1	13.8	6.1	7.2	-----	-----	17.7	17.5	16.5	6.5	2.7	3.2	-----	-----
134	34.7	27.4	30.3	18.1	9.5	1.4	-----	-----	21.3	14.7	16.4	8.7	4.4	.6	-----	-----
135	26.3	24.1	22.2	11.6	21.5	-----	-----	-----	13.5	12.6	12.1	4.9	11.6	-----	-----	-----
136	28.7	17.2	12.3	1.5	.7	7.8	-----	-----	15.5	8.2	5.4	.6	.3	4.1	-----	-----
137	31.1	21.1	19.4	10.5	3.3	12.1	-----	-----	16.1	10.9	9.3	5.2	1.4	6.0	-----	-----
138	25.1	15.1	9.3	.8	6.4	17.8	-----	-----	13.2	7.5	4.5	.4	3.1	9.5	-----	-----
139	28.8	20.9	23.1	6.9	.9	8.8	-----	-----	15.8	10.4	10.8	3.1	.4	4.4	-----	-----
140	30.4	23.5	25.9	18.3	10.4	.8	7.5	-----	16.3	11.8	13.1	8.4	4.4	.3	4.6	-----
145	27.4	27.1	19.5	10.2	2.3	25.7	-----	-----	15.7	13.8	9.3	5.1	1.1	16.9	-----	-----
146	37.1	35.0	31.5	26.0	18.7	2.5	14.3	-----	22.2	20.3	17.6	13.0	8.9	1.2	8.9	-----
147	32.9	32.3	29.3	24.1	17.4	17.7	-----	-----	19.1	18.4	15.9	12.3	8.4	11.3	-----	-----
148	28.3	26.4	20.8	12.8	8.1	1.7	21.7	-----	14.8	13.9	10.5	5.8	2.3	1.0	12.4	-----
149	27.2	24.8	19.4	13.9	7.4	-----	-----	-----	14.3	12.5	9.6	6.9	3.8	-----	-----	-----
150	31.4	30.1	26.1	17.5	13.8	2.6	-----	-----	18.2	16.9	14.0	9.1	5.8	1.4	-----	-----
151	25.9	29.1	19.8	11.4	9.6	17.3	-----	-----	14.2	15.9	9.5	5.1	4.2	9.4	-----	-----
152	34.7	34.4	31.7	25.5	21.6	16.5	24.1	-----	20.1	19.2	15.5	12.6	10.2	8.8	18.0	-----
153	31.3	31.4	24.5	23.9	19.3	18.2	-----	-----	17.3	16.4	14.3	12.7	10.9	10.6	-----	-----
154	26.6	26.4	21.3	19.6	19.0	13.1	7.5	6.4	14.6	14.0	11.9	9.7	8.5	6.0	3.4	2.8
155	28.7	28.5	25.1	21.8	18.4	11.8	-----	-----	16.2	15.6	12.9	11.1	8.6	7.5	-----	-----
156	21.9	18.5	9.6	3.6	2.5	33.7	-----	-----	10.9	8.9	4.6	1.5	1.2	30.8	-----	-----
157	19.4	16.4	9.4	5.1	3.1	19.1	15.1	-----	9.5	7.7	4.4	2.2	1.5	10.1	9.6	-----
158	33.0	30.5	29.5	28.0	27.8	24.5	21.1	17.1	17.3	16.6	16.0	14.9	14.5	12.6	10.5	8.3
159	25.9	21.0	12.2	10.8	5.2	4.1	12.1	7.8	13.9	10.7	5.7	5.0	2.3	1.9	6.0	3.9
160	30.4	28.7	28.9	23.7	20.6	11.6	10.6	15.8	15.9	15.6	15.6	12.0	10.1	5.6	5.0	8.2
163	34.3	28.8	21.1	13.4	-----	-----	-----	-----	18.4	15.6	10.3	6.8	-----	-----	-----	-----
164	24.2	19.7	13.5	11.2	5.7	-----	-----	-----	14.1	10.8	7.4	5.3	2.9	-----	-----	-----
165	30.1	25.7	15.5	14.9	8.6	5.7	13.8	12.5	16.7	13.6	8.6	6.9	3.9	2.7	7.2	7.0
166	27.9	25.9	23.8	21.4	15.8	14.8	17.4	-----	15.9	14.6	12.4	10.6	7.4	7.8	9.8	-----
167	27.6	26.9	20.5	17.1	12.2	15.0	21.5	21.6	14.9	13.3	10.1	8.1	5.6	7.6	12.0	12.1

Table 26

Porosity and absorption of burned samples of Southwest Pennsylvania clays and shales—Concluded

Sample number	Porosity percentage of burned volume								Absorption percentage of burned weight							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
168	30.2	30.2	29.9	25.1	19.7	-----	-----	-----	17.9	17.3	16.1	12.8	9.5	-----	-----	-----
169	33.0	28.6	18.5	9.5	13.4	17.2	21.3	-----	18.5	14.5	8.7	5.8	7.3	8.5	12.6	-----
170	27.6	25.3	20.3	18.2	15.3	15.2	15.9	18.5	14.6	13.1	9.8	8.7	7.3	7.8	8.2	9.9
171	21.9	18.3	10.7	7.4	16.7	26.3	27.4	-----	11.1	9.0	4.7	3.3	9.1	15.3	16.9	-----
172	34.4	30.3	28.8	27.3	25.4	23.0	19.9	16.9	18.2	16.7	16.1	15.1	12.8	11.8	9.9	8.0
173	24.7	21.7	20.3	9.3	-----	16.9	-----	-----	13.2	10.8	10.1	4.1	-----	8.9	-----	-----
174	35.4	32.3	23.0	16.1	17.1	-----	-----	-----	20.3	17.8	11.3	8.7	9.3	-----	-----	-----
175	28.2	25.5	23.5	21.1	16.4	14.0	15.0	18.7	15.3	13.2	11.9	10.2	7.9	6.6	7.4	9.8
176	35.0	35.3	34.4	25.8	16.0	14.0	-----	-----	21.0	20.9	19.6	13.3	7.4	7.3	-----	-----
177	27.2	28.3	28.9	24.2	20.4	16.2	18.1	26.7	14.9	15.3	15.6	12.7	10.3	8.6	10.0	16.4
178	29.8	30.2	30.2	27.8	27.2	20.5	17.1	11.7	17.1	17.3	16.9	15.3	14.3	10.4	8.3	5.5
179	33.6	32.4	30.7	23.8	14.9	7.0	4.9	1.3	18.5	17.2	16.8	12.1	7.1	3.0	2.7	.7
180	32.4	29.9	27.8	23.4	-----	5.0	-----	-----	18.4	17.1	14.3	14.3	12.9	10.5	2.2	4.5
181	31.9	30.8	30.4	24.9	23.2	16.4	8.0	-----	18.6	17.1	16.7	13.4	11.6	7.9	3.6	1.5
182	34.8	35.2	32.0	29.8	24.5	12.5	7.5	-----	21.4	20.7	19.5	17.1	12.6	5.9	4.5	-----
183	33.5	33.4	31.7	21.8	12.2	4.2	-----	1.6	19.7	19.3	17.7	11.2	5.6	1.7	-----	.7
185	28.5	27.6	26.0	19.2	11.4	5.3	-----	2.3	16.3	15.7	14.3	9.3	5.4	2.5	.8	1.2
186	35.2	34.4	33.6	19.4	10.7	5.2	5.7	-----	21.0	20.1	17.7	9.8	4.5	2.6	4.2	-----
187	26.7	26.2	21.8	16.2	13.5	6.2	-----	3.6	14.5	13.9	11.1	7.8	6.3	2.8	3.3	1.8
188	30.6	31.2	31.1	29.6	28.2	26.9	26.5	2.2	17.3	17.4	17.3	16.2	15.2	8.0	14.4	12.8
189	27.1	28.9	27.6	28.1	25.8	27.5	26.9	26.1	15.5	15.9	15.6	14.2	14.2	14.1	14.5	14.2
190	24.2	20.0	13.2	8.0	5.9	2.6	2.0	1.8	12.9	10.1	6.0	3.7	2.7	1.1	1.0	1.0
191	25.6	26.4	21.8	17.5	18.8	12.5	7.9	6.3	14.8	14.2	10.7	8.5	8.9	6.5	4.4	3.6
192	26.3	25.5	21.0	16.4	14.3	9.9	-----	2.2	14.4	13.6	10.9	7.6	6.7	4.6	2.8	.9
193	28.4	27.9	25.2	23.2	22.7	21.1	20.4	17.2	16.9	16.0	13.6	12.3	11.8	11.4	10.7	8.9
194	28.0	27.4	24.5	18.1	14.8	10.2	2.7	2.9	15.3	15.0	12.8	8.8	7.0	4.6	1.2	1.4
196	28.2	26.2	23.5	17.1	12.2	-----	-----	3.2	15.6	14.2	11.9	7.7	5.6	3.8	2.1	1.6
197	20.7	15.2	6.7	9.5	-----	-----	-----	-----	11.6	7.6	3.2	5.9	-----	-----	-----	-----
198	16.8	16.1	12.8	4.5	-----	-----	-----	-----	9.3	8.7	7.4	2.9	-----	-----	-----	-----
199	25.9	18.3	9.8	6.3	-----	-----	-----	-----	14.4	9.1	4.6	3.4	-----	-----	-----	-----
200	25.6	21.9	15.5	6.9	10.2	-----	-----	-----	14.5	11.6	7.6	3.1	6.0	-----	-----	-----
201	22.0	18.4	10.9	40.2	19.9	-----	-----	-----	11.8	9.4	5.4	21.6	17.3	-----	-----	-----
202	29.5	22.5	13.5	5.3	13.7	-----	-----	-----	16.5	11.5	6.4	2.4	10.6	-----	-----	-----
203	26.5	21.4	15.2	7.6	10.7	-----	-----	-----	15.0	11.5	7.6	3.7	7.1	-----	-----	-----
205	12.7	6.7	4.2	15.3	2.3	-----	-----	-----	6.6	3.6	2.3	7.7	1.3	-----	-----	-----
216	13.4	8.7	3.7	9.1	16.9	-----	-----	-----	7.4	4.8	1.7	4.4	10.0	-----	-----	-----
217	11.1	6.5	1.7	14.0	1.0	-----	-----	-----	5.0	2.8	0.8	7.5	0.5	-----	-----	-----
218	17.4	13.9	3.2	6.3	1.1	-----	-----	-----	8.5	6.5	1.4	3.0	0.6	-----	-----	-----
219	11.2	9.9	4.4	16.5	-----	-----	-----	-----	5.0	4.4	2.0	9.0	-----	-----	-----	-----
220	22.3	19.6	7.7	2.0	1.1	-----	-----	-----	11.4	9.5	3.4	1.2	.5	-----	-----	-----
221	22.5	18.4	8.7	5.6	1.2	-----	-----	-----	11.4	8.9	3.8	2.5	.6	-----	-----	-----
222	27.0	23.2	22.2	14.5	9.5	5.8	11.8	-----	14.3	11.9	10.7	6.8	4.4	3.0	6.3	-----
223	27.8	26.0	19.8	17.0	4.9	3.6	-----	-----	15.0	13.7	9.7	7.6	2.3	1.7	-----	-----
225	29.0	25.3	17.6	12.6	2.1	-----	-----	-----	15.3	13.0	8.2	5.8	1.1	-----	-----	-----
226	31.7	27.9	21.3	21.5	5.6	-----	-----	-----	17.1	14.8	10.5	18.0	2.7	-----	-----	-----
227	20.9	17.0	11.2	9.4	1.9	-----	-----	-----	10.3	7.8	4.8	4.1	.9	-----	-----	-----
228	22.1	11.0	7.9	8.2	5.9	-----	-----	-----	10.8	4.7	3.4	3.7	3.2	-----	-----	-----
229	27.3	22.0	12.9	10.8	19.8	-----	-----	-----	14.5	11.1	5.9	5.1	11.0	-----	-----	-----
230	20.4	14.3	16.1	23.6	42.3	-----	-----	-----	10.2	6.9	6.7	13.9	32.2	-----	-----	-----
231	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
232	31.3	-----	-----	10.0	-----	-----	-----	-----	18.0	-----	-----	5.1	-----	-----	-----	-----
233	24.9	21.5	16.3	11.7	7.2	11.4	-----	-----	12.4	10.5	7.7	5.3	3.3	5.9	-----	-----
234	12.3	7.0	5.6	3.9	5.7	1.6	1.6	-----	5.6	3.7	2.4	1.7	2.9	.9	.9	-----
235	13.7	8.2	6.7	9.5	1.0	-----	-----	-----	6.4	3.5	2.9	7.7	.4	-----	-----	-----
236	18.3	14.1	17.1	32.1	-----	-----	-----	-----	8.7	6.6	9.1	24.1	-----	-----	-----	-----
237	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
238	29.4	25.8	16.3	19.7	2.0	-----	-----	-----	16.2	13.7	7.9	10.6	1.1	-----	-----	-----
239	23.0	19.7	16.2	11.8	1.6	3.5	16.1	-----	11.9	9.8	7.7	5.3	.7	1.8	8.9	-----
240	29.2	40.7	-----	-----	-----	-----	-----	-----	24.3	24.3	-----	-----	-----	-----	-----	-----
241	29.2	14.4	18.0	1.1	1.9	6.9	-----	-----	14.3	7.0	9.1	.5	.9	4.0	-----	-----
243	25.1	17.1	16.5	-----	-----	-----	-----	-----	12.5	8.3	8.1	-----	-----	-----	-----	-----
244	24.6	22.3	20.6	-----	-----	-----	-----	-----	13.0	11.8	10.8	-----	-----	-----	-----	-----
250	28.0	26.6	23.2	23.5	16.7	6.4	1.6	3.3	15.5	14.8	12.1	12.2	8.2	2.8	.8	1.7
251	29.2	24.0	16.1	15.7	8.5	-----	-----	-----	14.8	12.1	7.4	7.4	4.4	-----	-----	-----
331A	25.0	23.4	18.7	19.0	7.4	8.7	7.2	8.8	13.6	12.4	9.3	9.5	3.5	5.3	4.8	6.7
331B	23.3	20.6	15.5	13.5	9.6	6.5	5.2	-----	12.7	12.8	7.5	6.4	4.0	3.9	3.0	-----
331C	24.4	22.3	16.3	14.1	8.3	6.6	7.6	-----	13.2	12.0	8.0	6.8	3.8	4.3	4.6	-----
358	21.5	19.3	12.6	1.3	1.1	3.8	-----	-----	10.4	9.3	5.6	.5	.5	2.1	-----	-----
376	35.9	33.5	26.0	20.4	11.1	7.8	6.6	13.4	10.0	18.4	13.1	9.5	4.0	3.4	2.9	6.0
377	28.7	19.3	9.1	3.0	1.9	2.8	8.9	12.6	15.4	9.3	4.0	1.2	.8	1.3	4.6	7.0
381	35.5	34.3	32.7	30.8	26.2	22.8	15.0	9.7	11.2	19.9	18.7	17.5	14.0	11.6	7.2	4.5
382	35.8	33.8	27.7	23.5	14.9	8.2	3.3	13.2	11.1	19.3	13.7	11.7	6.8	3.6	1.4	6.9
390	33.7	32.2	29.6	22.2	11.3	6.1	6.1	8.1	19.7	18.6	16.2	11.2	5.2	2.5	2.9	4.0

Table 27

Specific gravity of burned samples of Southwest Pennsylvania clays and shales

Sample number	Apparent specific gravity								Bulk specific gravity							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
82	2.50	2.51	2.26	2.08	2.23	-----	-----	-----	1.86	2.02	1.87	2.05	1.66	-----	-----	-----
83	2.46	2.45	2.35	2.22	2.08	-----	-----	-----	1.94	2.29	2.28	2.15	1.85	-----	-----	-----
84	2.91	2.83	2.73	2.45	2.33	-----	-----	-----	2.13	1.74	1.72	1.99	2.07	-----	-----	-----
85	2.71	2.38	2.37	2.29	2.12	-----	-----	-----	2.14	2.17	2.29	2.27	1.74	-----	-----	-----
86	2.52	2.52	2.46	2.45	2.31	2.27	2.22	-----	1.72	1.77	1.76	1.94	2.05	2.22	1.46	-----
87	2.56	2.66	1.98	2.7	2.54	2.35	2.38	-----	1.79	1.89	1.54	2.04	2.14	2.24	1.55	-----
88	2.49	2.51	2.33	2.38	2.33	2.02	-----	-----	1.89	2.08	2.04	2.34	2.28	1.95	-----	-----
89	2.63	2.72	2.65	2.33	2.39	2.42	2.26	2.2	2.09	2.28	2.29	2.10	2.16	2.24	1.89	2.08
90	2.59	2.54	2.5	2.62	2.05	-----	-----	-----	1.84	1.93	1.86	1.93	1.74	-----	-----	-----
91	2.6	2.48	2.58	2.22	2.14	2.03	-----	-----	1.88	2.06	2.24	2.12	1.98	1.74	-----	-----
92	2.52	2.51	2.37	2.26	2.38	2.13	-----	-----	1.96	2.16	2.15	2.22	2.22	1.92	-----	-----
93	2.66	2.52	2.52	1.83	1.57	-----	-----	-----	2.28	2.26	2.28	1.75	1.30	-----	-----	-----
94	2.41	2.44	2.37	2.22	2.14	2.12	-----	-----	1.85	1.77	1.78	2.22	2.14	1.84	-----	-----
95	2.34	2.54	2.59	2.3	1.71	-----	-----	-----	2.05	1.87	1.94	2.10	1.65	-----	-----	-----
96	2.20	2.75	2.54	2.57	1.87	-----	-----	-----	1.73	1.86	1.72	1.99	1.80	-----	-----	-----
97	2.68	2.47	2.60	2.54	2.07	1.99	-----	-----	2.59	1.85	1.95	2.12	1.65	1.39	-----	-----
98	2.58	2.50	2.23	2.3	2.19	2.15	-----	-----	1.76	1.89	1.77	2.22	2.16	2.12	-----	-----
99	2.63	2.60	2.63	2.32	2.32	2.18	-----	-----	1.76	2.15	2.42	2.29	2.21	2.02	-----	-----
100	2.6	2.45	2.58	2.27	2.40	2.28	-----	-----	1.83	1.92	2.08	2.09	2.24	1.92	-----	-----
101	2.6	2.58	2.71	2.48	2.26	2.19	2.34	2.17	1.77	1.85	1.87	1.99	1.99	2.06	2.24	2.07
102	2.72	2.58	2.74	2.4	2.38	2.12	2.25	-----	1.77	1.96	2.16	2.16	2.24	1.97	1.80	-----
103	2.58	2.28	2.66	2.1	2.2	-----	-----	-----	1.94	1.96	2.20	2.08	1.63	-----	-----	-----
104	2.66	2.54	2.27	2.05	1.9	2.03	-----	-----	2.01	2.19	2.23	2.09	1.76	1.56	-----	-----
105	2.71	2.62	2.58	2.95	2.23	-----	-----	-----	1.74	1.87	1.91	2.32	2.19	-----	-----	-----
106	2.82	2.65	2.63	2.36	-----	-----	-----	-----	1.75	1.76	1.76	2.05	-----	-----	-----	-----
107	2.64	2.4	2.34	2.25	2.31	2.02	-----	-----	1.91	2.11	2.09	2.22	2.21	1.62	-----	-----
108	2.56	2.41	2.62	2.39	2.35	2.23	-----	-----	1.86	2.12	2.12	2.30	2.32	1.94	-----	-----
109	2.57	2.60	2.76	2.53	2.22	1.95	-----	-----	1.76	1.94	1.97	2.38	2.14	1.94	-----	-----
110	2.37	2.48	2.44	2.06	2.24	2.36	-----	-----	2.07	2.09	2.34	2.02	2.23	1.99	-----	-----
111	2.66	2.57	2.54	2.21	2.25	2.46	-----	-----	1.77	1.94	1.88	2.15	2.23	-----	-----	-----
112	2.58	2.55	2.66	2.47	2.29	2.36	2.20	2.06	1.83	2.13	2.13	2.22	2.09	2.20	1.81	1.77
113	2.47	2.52	2.45	2.18	2.62	2.21	-----	-----	1.75	2.05	1.92	2.01	2.44	2.10	-----	-----
114	2.68	2.63	2.61	2.41	2.59	2.66	2.21	-----	1.52	1.57	1.52	1.62	2.92	2.17	1.81	-----
115	2.64	2.85	2.69	2.47	2.07	-----	-----	-----	1.93	2.06	1.97	2.19	1.85	-----	-----	-----
116	2.48	2.22	2.51	2.51	2.38	2.52	2.24	2.24	1.81	1.81	1.89	1.98	2.12	2.34	2.17	1.97
117	2.59	2.60	2.31	2.19	2.18	2.01	-----	-----	1.89	2.12	2.07	2.17	2.16	2.01	-----	-----
126	2.71	2.62	2.78	2.52	2.42	2.46	2.07	-----	2.24	2.26	2.50	2.21	2.24	2.31	1.69	-----
127	2.49	2.50	2.52	2.56	2.57	2.39	2.29	2.16	1.84	2.01	2.07	2.16	2.33	2.27	2.06	1.97
128	2.33	2.46	2.41	2.21	1.96	-----	-----	-----	1.88	2.12	2.19	2.03	1.36	-----	-----	-----
129	2.59	2.48	2.66	2.32	2.33	-----	-----	-----	1.73	1.88	2.35	2.22	2.31	-----	-----	-----
130	2.32	2.53	2.48	2.23	2.33	2.04	-----	-----	1.83	1.82	1.83	2.16	2.31	1.97	-----	-----
131	2.61	2.63	2.50	2.63	2.34	2.02	-----	-----	1.77	1.94	1.90	2.34	2.31	1.89	-----	-----
132	2.76	2.65	2.99	2.36	2.28	2.23	-----	-----	1.90	2.22	2.25	2.25	2.21	1.93	-----	-----
133	2.42	2.63	2.49	2.45	2.43	2.44	-----	-----	1.69	1.80	1.76	2.11	2.28	2.27	-----	-----
134	2.49	2.56	2.65	2.53	2.39	2.28	-----	-----	1.63	1.86	1.85	2.07	2.16	2.24	-----	-----
135	2.64	2.53	2.37	2.65	2.37	-----	-----	-----	1.94	1.92	1.85	2.35	1.86	-----	-----	-----
136	2.59	2.50	2.62	2.46	2.44	2.06	-----	-----	1.85	2.07	2.30	2.42	2.43	1.90	-----	-----
137	2.79	2.56	2.57	2.27	2.49	2.31	-----	-----	1.93	2.01	2.08	2.03	2.41	2.03	-----	-----
138	2.53	2.43	2.25	2.29	2.21	2.28	-----	-----	1.90	2.05	2.04	2.27	2.07	1.87	-----	-----
139	2.57	2.49	2.65	2.26	2.32	2.17	-----	-----	1.83	2.02	2.06	2.19	2.31	1.99	-----	-----
140	2.68	2.60	2.66	2.66	2.60	2.25	2.41	-----	1.87	1.99	1.97	2.17	2.33	2.23	1.63	-----
145	2.40	2.68	2.62	2.23	2.10	2.02	-----	-----	1.74	1.95	2.11	2.00	2.05	1.52	-----	-----
146	2.67	2.66	2.49	2.70	2.58	2.11	1.85	-----	1.67	1.72	1.78	1.80	2.14	2.05	1.59	-----
147	2.57	2.61	2.61	2.58	2.50	1.91	-----	-----	1.73	1.76	1.84	1.96	2.07	1.57	-----	-----
148	2.67	2.50	2.51	2.46	2.47	2.05	2.22	-----	1.97	1.90	1.98	2.23	2.27	2.02	1.74	-----
149	2.61	2.63	2.53	2.33	2.10	-----	-----	-----	1.90	1.98	2.04	2.01	1.94	-----	-----	-----
150	2.51	2.56	2.53	2.33	2.77	2.01	-----	-----	1.73	1.79	1.87	1.93	2.39	1.96	-----	-----
151	2.47	2.57	2.61	2.52	2.51	2.25	-----	-----	1.83	1.82	2.09	2.23	2.27	1.86	-----	-----
152	2.65	2.74	3.10	2.73	2.71	2.26	-----	-----	1.73	1.80	2.06	2.02	2.12	1.89	-----	-----
153	2.52	2.80	2.23	2.49	2.20	2.10	-----	-----	1.81	1.92	1.71	1.89	1.77	1.72	-----	-----
154	2.47	2.56	2.29	2.52	2.76	2.51	2.39	2.39	1.82	1.88	1.80	2.02	2.24	2.18	2.21	2.24
155	2.47	2.56	2.60	2.51	2.64	1.78	-----	-----	1.77	1.83	1.94	1.96	2.15	1.57	-----	-----
156	2.57	2.54	2.28	2.44	2.10	1.65	-----	-----	2.01	2.08	2.07	2.35	2.05	1.09	-----	-----
157	2.54	2.57	2.32	2.43	2.14	2.34	1.86	-----	2.04	2.15	2.11	2.31	2.07	1.89	1.57	-----
158	2.84	2.63	2.62	2.61	2.66	2.58	2.55	2.38	1.90	1.83	1.79	1.88	1.92	1.95	2.01	2.06
159	2.52	2.47	2.41	2.41	2.38	2.25	2.31	2.14	1.87	1.95	2.19	2.17	2.26	2.16	2.02	1.97
160	2.74	2.58	2.60	2.54	2.56	2.34	2.34	1.65	1.91	1.84	1.85	1.97	2.04	2.07	2.09	1.93
163	2.70	2.60	2.59	2.33	-----	-----	-----	-----	1.77	1.85	1.53	2.13	-----	2.02	-----	-----
164	2.26	2.28	2.43	1.59	1.95	-----	-----	-----	1.72	1.82	2.06	2.12	1.97	1.74	1.64	-----
165	2.46	2.56	2.50	2.52	2.41	2.26	2.23	2.05	1.80	1.89	2.06	2.14	2.21	2.13	1.93	1.80
166	2.44	2.41	2.52	2.56	2.51	2.23	2.15	-----	1.76	1.78	1.91	1.95	2.11	1.90	1.77	-----
167	2.55	2.77	2.56	2.52	2.44	2.32	2.28	2.26	1.85	2.03	2.03	2.09	2.15	1.97	1.79	1.79

Table 27

Specific gravity of burned samples of Southwest Pennsylvania clays and shales—Concluded

Sample number	Apparent specific gravity								Bulk specific gravity							
	Degrees Centigrade								Degrees Centigrade							
	1000	1050	1100	1150	1200	1250	1300	1350	1000	1050	1100	1150	1200	1250	1300	1350
168	2.51	2.52	2.65	2.62	2.60	2.32	2.14	-----	1.69	1.75	1.85	1.96	2.09	2.02	-----	1.88
169	2.66	2.75	2.61	2.52	2.51	2.32	2.14	-----	1.78	1.97	2.13	2.28	2.20	1.86	1.69	-----
170	2.61	2.59	2.58	2.54	2.45	2.30	2.29	2.25	1.89	1.93	2.06	2.08	2.10	1.95	1.93	1.87
171	2.53	2.50	2.53	2.41	2.38	2.32	2.24	-----	1.98	2.04	2.25	2.24	1.87	1.71	1.62	-----
172	2.88	2.61	2.53	2.51	2.56	2.53	2.51	2.47	1.89	1.81	1.81	1.82	1.93	1.95	2.01	2.05
173	2.49	2.56	2.57	2.48	-----	2.29	-----	-----	1.87	2.01	2.04	2.25	-----	1.90	-----	-----
174	2.71	2.68	2.65	2.57	2.51	-----	-----	-----	1.75	1.81	2.04	2.13	2.11	1.53	-----	-----
175	2.58	2.59	2.59	2.60	2.48	2.45	2.39	2.35	1.85	1.93	1.98	2.05	2.07	2.11	2.03	1.91
176	2.56	2.62	2.68	2.61	2.55	2.22	-----	-----	1.67	1.69	1.76	1.93	2.15	1.91	-----	-----
177	2.51	2.58	2.64	2.50	2.49	2.24	2.21	2.22	1.83	1.85	1.87	1.89	1.98	1.88	1.81	1.63
178	2.49	2.50	2.55	2.58	2.62	2.48	2.48	2.42	1.75	1.74	1.78	1.81	1.90	1.97	2.06	2.14
179	2.74	2.66	2.62	2.59	2.48	2.47	1.97	1.96	1.82	1.89	1.92	1.98	2.09	2.30	2.02	1.94
180	2.60	2.50	2.64	2.43	-----	2.41	-----	-----	1.76	1.75	1.82	1.85	-----	2.3	-----	-----
181	2.52	2.60	2.62	2.48	2.42	2.47	2.37	-----	1.72	1.80	1.88	1.86	2.00	2.06	2.18	-----
182	2.48	2.63	2.67	2.70	2.60	2.44	1.80	-----	1.62	1.70	1.75	1.85	1.95	2.14	1.65	-----
183	2.56	2.60	2.63	2.50	2.50	2.44	-----	2.17	1.70	1.73	1.79	1.94	2.18	2.33	-----	2.13
185	2.45	2.42	2.45	2.58	2.36	2.28	-----	2.09	1.75	1.76	1.82	2.08	2.08	2.16	-----	1.95
186	2.59	2.60	2.85	2.45	2.64	2.06	1.42	-----	1.67	1.70	1.89	1.98	2.35	1.96	1.35	-----
187	2.51	2.52	2.52	2.48	2.46	2.36	-----	2.06	1.84	1.87	1.97	2.68	2.14	2.21	-----	1.98
188	2.55	2.59	2.60	2.60	2.59	2.19	2.50	2.27	1.77	1.79	1.80	1.83	1.86	1.86	1.84	1.76
189	2.40	2.52	2.44	2.76	2.44	2.69	2.54	2.48	1.74	1.81	1.77	1.98	1.81	1.95	1.86	1.84
190	2.48	2.45	2.52	2.36	2.31	3.06	2.0	1.83	1.87	1.98	2.2	2.16	2.17	2.26	1.98	1.79
191	2.34	2.54	2.60	2.50	2.59	2.18	1.92	1.84	1.74	1.87	2.03	2.06	2.11	1.91	1.77	1.73
192	2.47	2.52	2.45	2.56	2.47	2.38	-----	2.24	1.82	1.88	1.93	2.14	2.11	2.15	-----	2.19
193	2.35	2.42	2.46	2.95	2.98	2.35	2.40	2.33	1.69	1.75	1.84	1.88	1.91	1.86	1.90	1.93
194	2.55	2.52	2.09	2.50	2.46	2.45	3.0	2.78	1.83	1.83	1.92	2.05	2.10	2.2	2.2	1.98
196	2.52	2.51	2.58	2.69	2.48	-----	-----	2.3	1.80	1.85	1.97	2.23	2.18	-----	-----	1.96
197	2.24	2.36	2.27	2.51	-----	-----	-----	-----	1.78	2.00	2.11	1.61	-----	-----	-----	-----
198	2.15	2.19	1.98	1.62	-----	-----	-----	-----	1.79	1.84	1.73	1.55	-----	-----	-----	-----
199	2.44	2.46	2.32	1.97	-----	-----	-----	-----	1.80	2.01	2.09	1.85	-----	-----	-----	-----
200	2.36	2.40	2.40	2.33	1.88	-----	-----	-----	1.76	1.89	2.03	2.17	1.70	-----	-----	-----
201	2.31	2.41	2.28	3.10	1.44	-----	-----	-----	1.87	1.96	2.02	1.85	1.15	-----	-----	-----
202	2.55	2.52	2.44	2.30	1.51	-----	-----	-----	1.79	1.95	2.12	2.18	1.29	-----	-----	-----
203	2.40	2.36	2.35	2.22	1.71	-----	-----	-----	1.77	1.86	2.00	2.05	1.52	-----	-----	-----
215	2.51	2.50	2.38	2.20	2.28	-----	-----	-----	2.13	2.28	2.25	1.86	2.21	-----	-----	-----
216	2.43	2.43	2.25	2.25	2.04	-----	-----	-----	2.06	2.17	2.17	2.05	1.70	-----	-----	-----
217	2.50	2.48	2.21	2.18	1.89	-----	-----	-----	2.23	2.32	2.17	1.87	1.87	-----	-----	-----
218	2.49	2.48	2.40	2.27	1.94	-----	-----	-----	2.06	2.13	2.32	2.12	1.92	-----	-----	-----
219	2.50	2.48	2.27	2.19	-----	-----	-----	-----	2.22	2.23	2.17	1.83	-----	-----	-----	-----
220	2.52	2.54	2.47	2.34	2.07	-----	-----	-----	1.96	2.05	2.27	2.27	2.05	-----	-----	-----
221	2.46	2.53	2.50	2.36	2.04	-----	-----	-----	1.96	2.06	2.29	2.22	2.01	-----	-----	-----
222	2.58	2.54	2.68	2.50	2.38	2.07	2.06	-----	1.89	1.95	2.08	2.13	2.15	1.95	1.88	-----
223	2.55	2.56	2.56	2.69	2.26	2.06	-----	-----	1.85	1.90	2.05	2.23	2.15	2.05	-----	-----
225	2.67	2.61	2.59	2.45	1.98	-----	-----	-----	1.89	1.94	2.14	2.14	1.93	-----	-----	-----
226	2.71	2.61	2.57	2.62	2.15	-----	-----	-----	1.86	1.88	2.03	2.15	2.03	-----	-----	-----
227	2.56	2.63	2.60	2.54	2.14	-----	-----	-----	2.03	2.18	2.30	2.30	2.10	-----	-----	-----
228	2.61	2.58	2.48	2.39	1.95	-----	-----	-----	2.03	2.30	2.18	2.19	1.83	-----	-----	-----
229	2.58	2.53	2.51	2.37	2.26	-----	-----	-----	1.88	1.97	2.19	2.12	1.81	-----	-----	-----
230	2.52	2.42	2.40	2.22	2.27	-----	-----	-----	2.00	2.07	2.07	1.70	1.31	-----	-----	-----
231	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
232	2.54	-----	-----	2.18	-----	-----	-----	-----	1.75	-----	-----	1.96	-----	-----	-----	-----
233	2.24	2.60	2.54	2.49	2.34	2.17	-----	-----	1.99	2.04	2.13	2.20	2.17	1.93	-----	-----
234	2.49	2.41	2.46	2.37	2.08	1.87	1.75	-----	2.18	2.21	2.32	2.28	1.95	1.84	1.73	-----
235	2.46	2.56	2.46	2.22	2.09	-----	-----	-----	2.13	2.34	2.30	2.01	2.07	-----	-----	-----
236	2.53	2.46	2.26	1.91	-----	-----	-----	-----	2.11	2.01	1.88	1.33	-----	-----	-----	-----
237	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
238	2.56	2.53	2.45	2.32	2.60	-----	-----	-----	1.81	1.88	2.05	1.86	1.76	-----	-----	-----
239	2.52	2.49	2.52	2.50	2.27	1.99	2.17	-----	1.94	2.00	2.10	2.21	2.25	1.93	1.82	-----
240	2.10	1.81	-----	-----	-----	-----	-----	-----	1.61	1.68	-----	-----	-----	-----	-----	-----
241	2.47	2.41	2.46	-----	-----	-----	-----	-----	1.75	2.06	2.01	1.99	2.00	1.71	-----	-----
283	2.49	2.47	2.42	-----	-----	-----	-----	-----	1.86	2.05	2.02	-----	-----	-----	-----	-----
284	2.18	2.44	2.40	-----	-----	-----	-----	-----	1.90	1.90	1.91	-----	-----	-----	-----	-----
320	2.51	2.44	2.50	2.51	2.43	2.44	2.05	1.99	1.81	1.79	1.92	1.92	2.03	2.27	2.01	1.93
321A	2.78	2.61	2.59	2.52	2.10	-----	-----	-----	1.97	1.98	2.17	2.12	1.92	-----	-----	-----
331A	2.44	2.44	2.50	2.46	2.45	1.81	1.61	1.45	1.88	1.88	2.01	1.99	2.08	1.65	1.50	1.32
331B	2.38	2.44	2.44	2.43	2.65	1.75	1.79	-----	1.83	1.93	2.06	2.10	2.39	1.66	1.69	-----
331C	2.43	2.40	2.42	2.40	2.38	2.30	2.55	-----	1.83	1.86	2.03	2.06	2.18	1.54	1.63	-----
358	2.64	2.55	2.58	2.41	2.04	1.89	-----	-----	2.07	2.06	2.34	2.38	2.02	1.82	-----	-----
376	2.68	2.73	2.68	2.68	2.52	2.42	2.44	2.22	1.72	1.82	1.99	2.13	2.24	2.23	2.28	1.93
377	2.61	2.57	2.50	2.49	2.38	2.24	2.12	2.06	1.87	2.07	2.28	2.40	2.34	2.18	1.93	1.80
381	2.60	2.63	2.60	2.55	2.53	2.54	2.46	2.38	1.67	1.73	1.75	1.76	1.87	1.96	2.09	2.15
382	2.64	2.65	2.78	2.74	2.56	2.43	2.45	2.20	1.69	1.75	2.01	2.0	2.18	2.23	2.37	1.91
390	2.57	2.57	2.60	2.55	2.45	2.53	2.23	2.21	1.71	1.74	1.83	1.99	2.18	2.38	2.09	2.04

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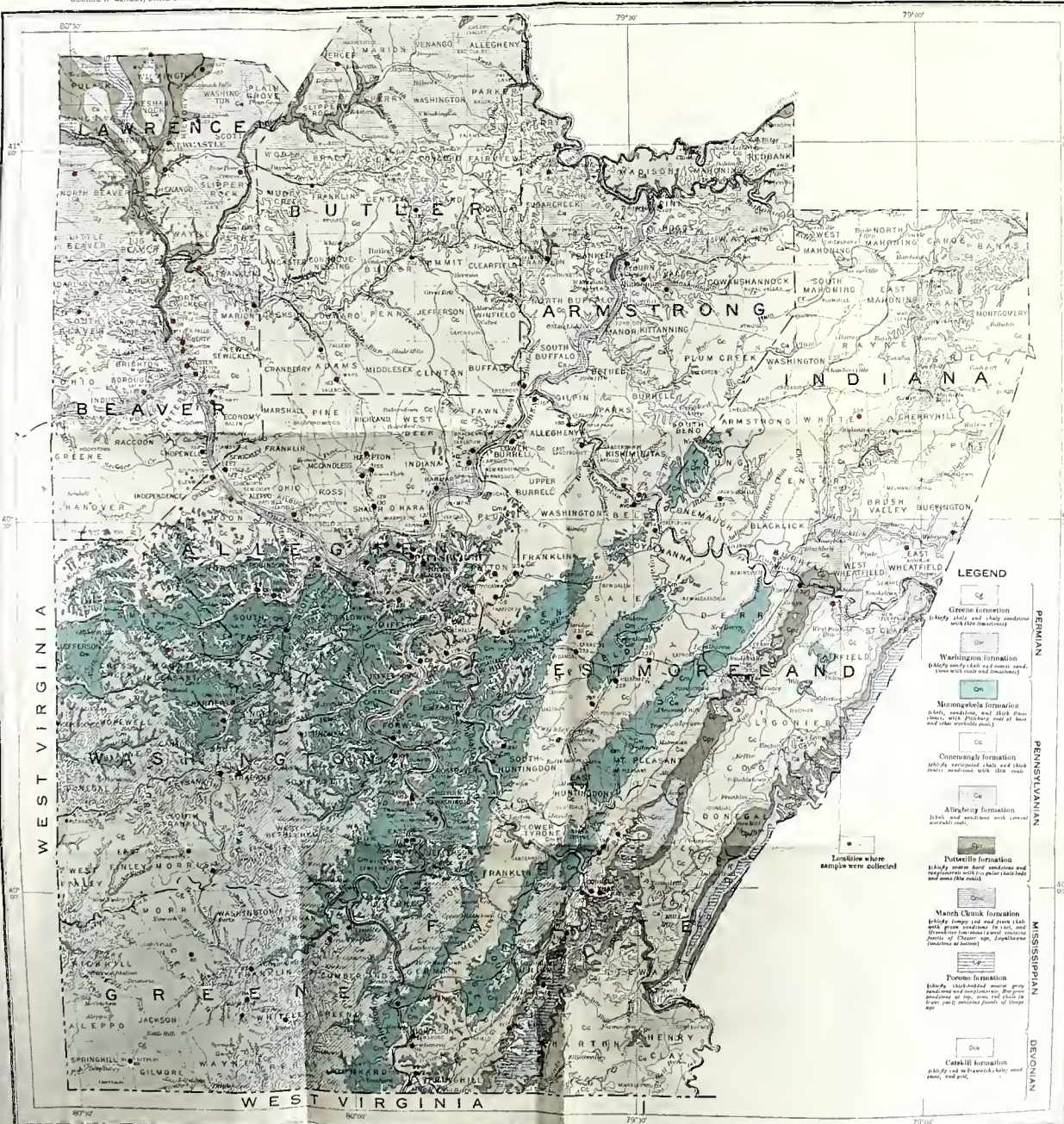
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GEOLOGIC MAP OF SOUTHWESTERN PENNSYLVANIA
 showing location of clay samples

PENNSYL

T



